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TECHNICAL NOTE

A new computer-assisted technique to aid personal identification

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Abstract The paper describes a procedure aimed at identification from two-dimensional (2D) images (video-surveillance tapes, for example) by comparison with a three-dimensional (3D) facial model of a suspect. The application is intended to provide a tool which can help in analyzing compatibility or incompatibility between a criminal and a suspect's facial traits. The authors apply the concept of "geometrically compatible images". The idea is to use a scanner to reconstruct a 3D facial model of a suspect and to compare it to a frame extracted from the video-surveillance sequence which shows the face of the perpetrator. Repositioning and reorientation of the 3D model according to subject's face framed in the crime scene photo are manually accomplished, after automatic resizing. Repositioning and reorientation are performed in correspondence of anthropometric landmarks, distinctive for that person and detected both on the 2D face and on the 3D model. In this way, the superimposition between the original two-dimensional facial image and the three-dimensional one is obtained and a judgment is formulated by an expert on the basis of the fit between the anatomical facial districts of the two subjects. The procedure reduces the influence of face orientation and may be a useful tool in identification.

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Introduction

Eurostat (http://www.ec.europa.eu/eurostat) has recorded a rise in police reported crime figures between 1995 and 2005 in Europe, due to increasing violent crime (theft, assaults, robberies etc.). The general trend in European Union countries was an increase of about 4%. In 2005, 2,977 bank robberies in Italy were perpetrated, with an increase of about 2% relative to 2004, while in Germany 728, France 445, Spain 484, Greece 155, Portugal 127, UK 122, Belgium 121, Poland 65 and Slovakia 23 (http://www.abi.it) [1]. A total of 56 million Euros was stolen from banks in Italy in 2006, with an increase of 5.1% with respect to 2005 [2]. The use of video-surveillance cameras has been increased to face and deter crime. At present, it is difficult to find a bank without a video-surveillance system.

Thus, identification by video-surveillance systems is more frequently becoming the object of medicolegal and anthropological investigations. Identification of the living started in Europe between the end of the nineteenth and the beginning of the twentieth centuries by Bertillon, who introduced a method of personal identification based on anthropology, i.e. on the study of body measurements for anthropological comparison and classification [2, 3]. This has since been used as an identification procedure.

With the increasing diffusion of video recording systems as crime deterring devices, it has become a routine procedure to compare images of a suspect with those obtained from surveillance films, paying special attention to the morphological characteristics of some peculiar anatom-

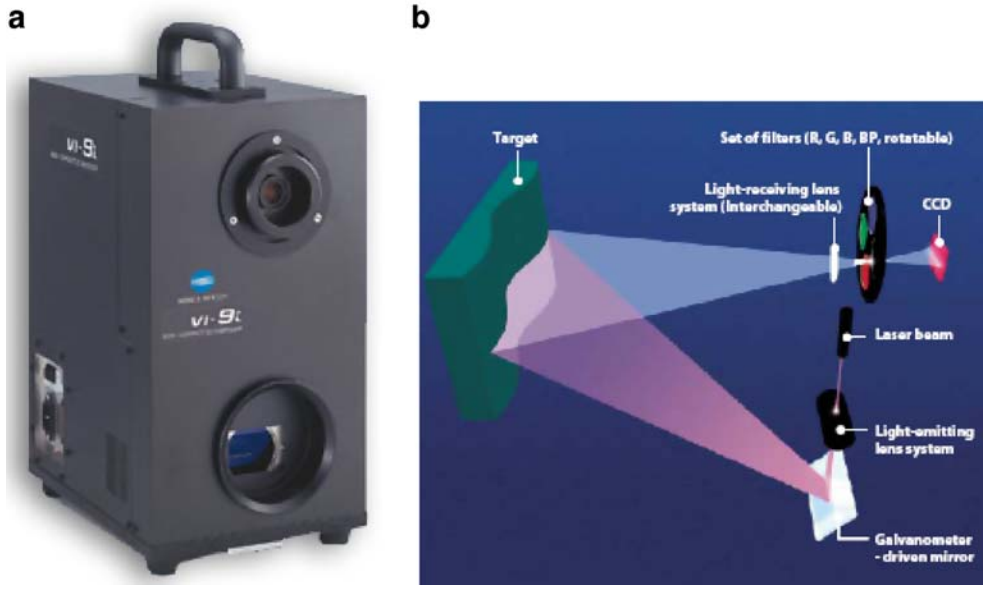

Fig. 1 Konica Minolta VI-9i: **a** device and **b** measurement principle

ical parts (such as eyes, nose, mouth and ears) of the head. In this field, Halberstein [4] based his identification judgment on facial indices calculated on two-dimensional (2D) photographs (for example, nose length/head length, ear length/face height) of the videotaped subject and of the suspect by using nine anthropometric measurements taken from the head and face.

These quantitative methodologies often meet limits of a practical nature: in the majority of cases, the starting images have an informative content which is too poor for applying the procedure in a reliable manner. Quantitative identification procedures can be split into two main categories: 2D–2D methods, based on the comparison between the photos of the subject to be identified (the "criminal") and the ones of the subject under investigation (the "suspect"), and so-called three-dimensional (3D)–2D techniques, where a photo of the criminal and a 3D model of the suspect's face are compared. There are also 3D–3D matching methods, such as that presented in [5]. 3D–3D techniques are more reliable because they overcome some limitations typical of the other two methodologies but they cannot be applied in actual situations until traditional 2D recording systems are substituted with 3D recording devices (such as stereoscopic systems and 3D scanners).

The scientific basis of personal identification from 2D images has been established by anthropometry, which entrusts identification to morphological characters and classifications [6] or numerical indices, computed from measurements directly performed on images. Identification by simple morphological classification of traits is obviously insufficient, whereas the use of indices has recently been severely criticised [7].

Amelioration in personal identification can be achieved through the use of 3D–2D techniques. From this perspective, important results were obtained by Yoshino's team [8]. According to the results obtained by Yoshino et al., who have worked on a wide sample of people, the method provides recognition when the mean distance between corresponding landmarks is lower than 2.5 mm; applying this threshold, Yoshino did not observe any false positive cases. Some limitations of this method, such as dependence on the presence of disguises or other tricks to hide one's identity, were partially overcome by adding a new parameter, based on the evaluation of the face profile [9].

Goos et al. [10] proposed a semi-automatic identification technique able to estimate original camera positioning and orientation on the basis of facial landmarks positioned both on the photo of the perpetrator and on the three-dimensional facial model of a suspect.

All these methodologies provide a quantitative identification judgment, but they completely bypass experts' contribution, fundamental in identity verification. More-

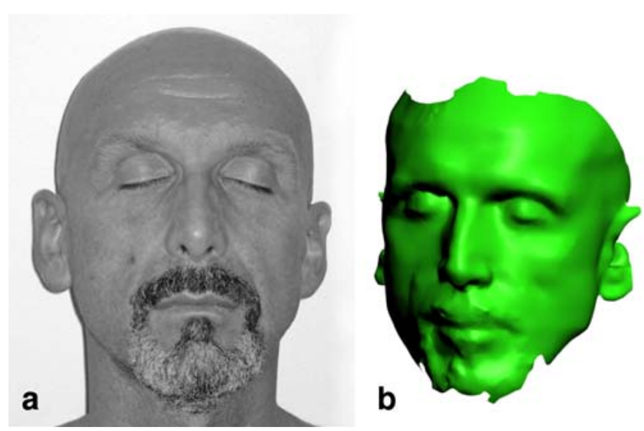

Fig. 2 An example of a 3D mask (**b**) obtained from the acquisition of the face of a volunteer (**a**) via the Konica Minolta VI-9i

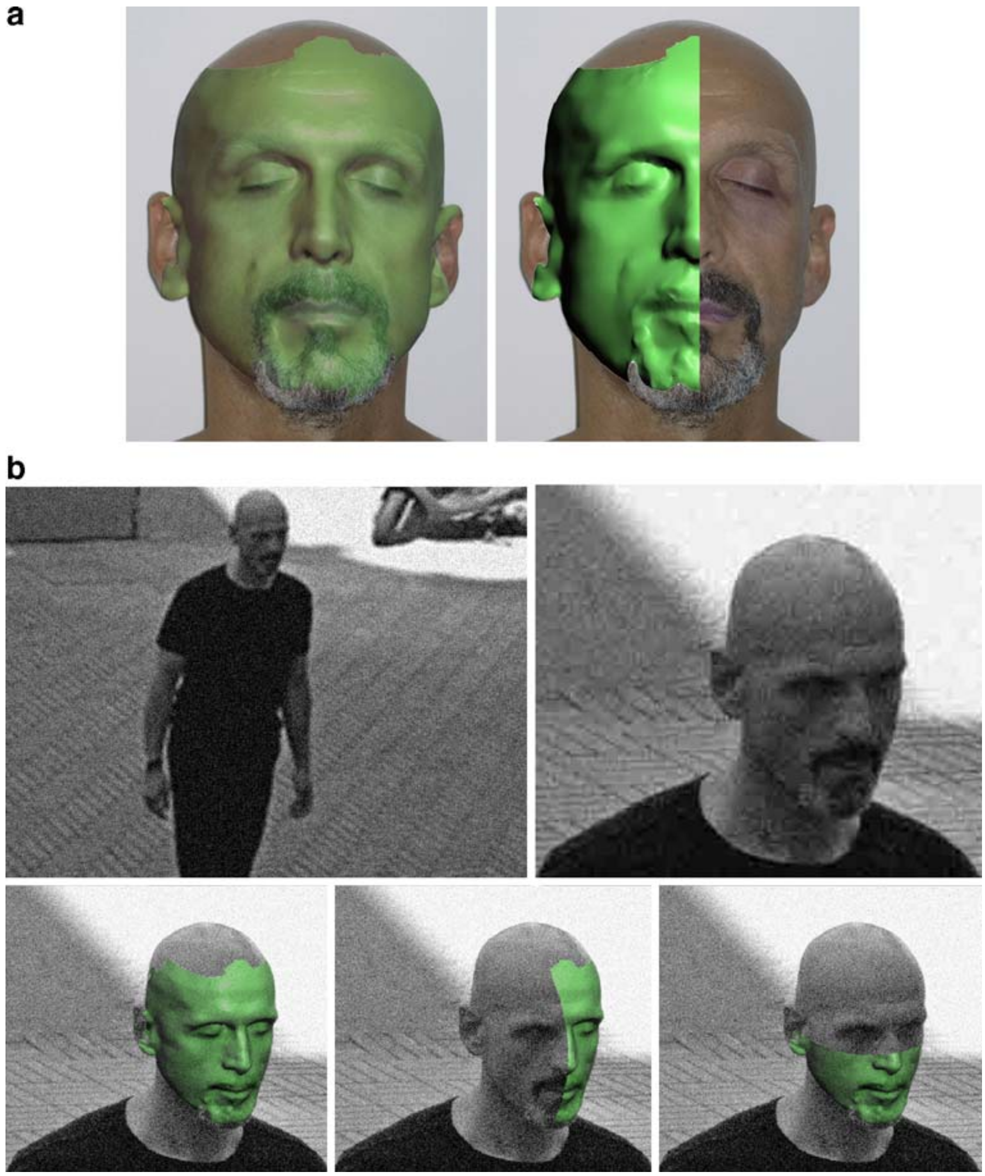

Fig. 3 **a** 3D mask validation via superimposition of the “virtual face” on the picture of the face of the volunteer used to generate the 3D mask. **b** The 3D mask generated from the face of a known person is superimposed on the face of the subject to be identified (simulated example)

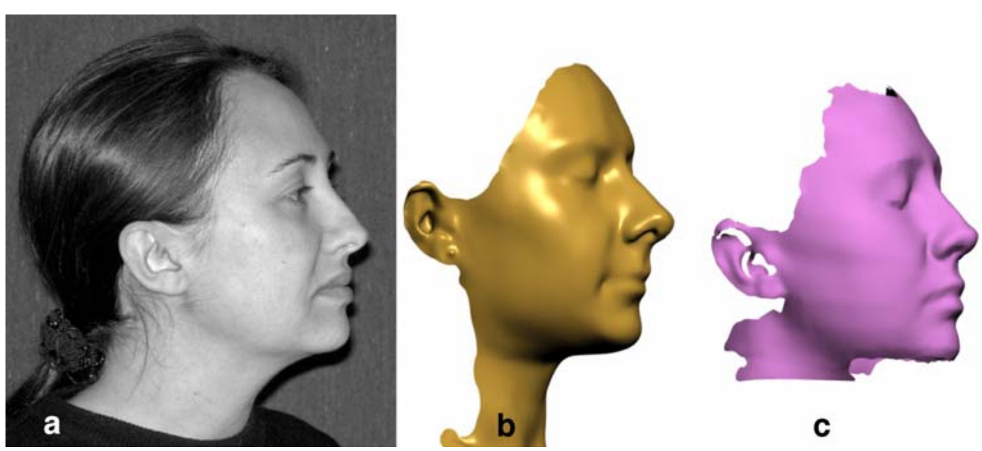

Fig. 4 **a** Simulated good quality image from surveillance system; **b**, **c** 3D models of two “suspects” (volunteer) with similar facial features

Fig. 5 3D model of suspect "b" superimposed to the face of the "offender". In the absence of a clinical history that could justify the discrepancies, the identity is excluded

over, they limit face examination to only a few landmarks, hardly detectable and characterised by a positioning error greater than 2 mm.

Morphological correspondence of facial traits is also used. It is becoming a routine procedure to compare images of a suspect with those obtained from surveillance filming, paying special attention to the morphological characteristics of some peculiar anatomical parts of the head, which are the most discriminant. Among new search topics in forensic anthropology, identification of the living is therefore more frequently asked and performed by anthropologists [4, 11, 12].

To this effect, some authors [13] record the subject under investigation under the same conditions as the subject to be identified. The recognition is performed by comparing the craniofacial districts of the two subjects, through a numerical analysis of the two images.

The present work introduces a semi-automatic methodology for personal identity verification. The method is intended to provide experts with useful information to help in formulating compatibility and incompatibility judgments by comparing facial traits of the framed subject and those of one (or more) suspect. The proposed procedure arises to surpass some limitations of classical methods (like orientation problems or the necessity to bring the defendant or the defendants at the crime scene) towards a more flexible method.

Technical procedure

The target is reached by acquiring a three-dimensional model of the defendant, which is projected onto the original crime photo, resized, repositioned and reoriented via software in order to obtain the best match with the subject's face in the two-dimensional photo. Identification is then performed by an expert, on the basis of the fit of the somatic facial traits of the criminal (framed in the original photo) and those of the defendant (projected three-dimensional model).

The methodology follows guidelines of a procedure developed by the authors and used in height estimation of subjects filmed on video-surveillance systems [1]. Starting from the knowledge of the three-dimensional coordinates of at least six scene points (and their two-dimensional correspondence on the image), a virtual camera with parameters entirely equivalent to those of the camera that produced the original image is created. The idea is to generate a virtual camera following the main guidelines applied in height estimation and use this camera to film the defendant's 3D facial model. In this case, it is obtained by an automatic resizing of the model according to the filmed subject's face in the photo. Repositioning and orientation are manually accomplished, once the camera is generated. In this way, the best match is performed. Final judgment is expressed by experts who analyse compatibility between the somatic facial traits of the two subjects.

The nodal point is the acquisition of the three-dimensional model of the defendant. The chosen device is the laser scanner VI-9i by Konica Minolta (Konica Minolta Holding Inc., Tokyo, Japan, www.konicaminolta-3d.com; Fig. 1). The scanner works on triangulation to acquire points from a 3D object (in this case a face). The charge-coupled device camera receives the light reflected from the surface of the subject. Surface shape measurements of the

Fig. 6 3D model of suspect "c" superimposed on the offender face. With this kind of image, it is easy to demonstrate the objectivity of the corresponding morphological facial features

subject are obtained through triangulation and converted into a 3D polygon mesh. Another characteristic is that the laser stripe is moved by a galvanometer, so higher scanning speed can be obtained (only 2.5 s.). The scanner is also provided with three optics (tele=25 mm, middle=14 mm and wide=8 mm), to be selected according to the measurement target. In this application, middle lens was chosen. With this setting, a field of 658×494×1,058 mm ensures an accuracy of ±0.05 mm (according to manufacturer's specifications).

Figure 2 shows an example of a 3D mask (b) obtained by acquiring the face of a volunteer (a) via the Konica Minolta device. To check the reliability of the 3D model, the virtual face is superimposed on the high quality picture of the face used to produce it to highlight any error in the acquisition process (Fig. 3a).

Especially when video-surveillance images are characterised by low resolution and when no metric or quantitative analysis can be performed, the 3D mask of a suspect is superimposed on the face of the filmed offender as in the simulated example in images in Fig. 3b. Influence of image quality, in terms of pixel dimension (image resolution), has been analysed in a previous work [14], where images at high resolution were degraded till it was not possible to distinguish clearly facial traits. Results showed that when pixel dimension exceeded 1 mm, reliability of the technique was no longer guaranteed, so in this case, it is not reasonable to apply the recognition technique. When good quality images are available from surveillance systems, the method gives the expert the opportunity to observe and judge the degree of correspondence between the morphology of face characteristics of the offender and those of the suspect (or suspects) as shown in the simulated example in Figs. 4, 5 and 6.

Results and conclusions

Frequently medical examiners, forensic anthropologists or other "experts" are asked to express a judgment about the possibility that a criminal visible in an image can be identified as a known person/suspect. Cephaloscopic (qualitative) and cephalometric (quantitative) techniques of face comparison are affected by the problems discussed in the introduction so there is the need for new tools for identification of the living face.

The proposed method is thought to produce high quality and reliable facial superimposition so that anthropologists or medical examiners may compare facial features and indicate corresponding traits or discrepancies in a court of law. Even before automated diagnostic systems, the scientific community needs, first of all, a tool that can help in a diagnosis of identity. With an accuracy of ±0.05 mm, the acquired 3D masks of suspects can be reliably superimposed to the face of offenders and experts can judge the produced images via qualitative and quantitative methods. One of the disadvantages consists in the high cost of the laser device (from about 25,000 to about 55,000 euros); however, less expensive commercial scanners and custom devices are being produced.

Another problem could be found in the use of 3D modelling software but further research is oriented toward the development of user friendly applications which could simplify and partially automate the approach to 3D modelling for facial identification. Nonetheless, this method shows considerable assets with respect to the previously mentioned methods which use indices and observation of gross general facial morphology for comparative identification. This, however, is only a contribution, to be used in conjunction with other techniques such as a "classical" photographic comparison, towards a better methodological approach to the actual comparison.

It may therefore aid identification but in order to reach an algorithm for positive identification, research now must be performed on several issues, i.e. the actual significance of a "perfect" or "near perfect" match. As the hardware and software are not yet "user friendly", today, research also aims at developing an easy to use 3D scanner and 3D modelling software in order to test repeatability between trained operators.

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