Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

Canadian Intellectual Property Office
An agency of Industry Canada

CA 2584611 A1 2006/05/04

(21) 2 584 611

(12) DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION

(13) A1

(86) Date de dépôt PCT/PCT Filing Date: 2005/10/26
(87) Date publication PCT/PCT Publication Date: 2006/05/04
(85) Entrée phase nationale/National Entry: 2007/04/19
(86) N° demande PCT/PCT Application No.: GB 2005/004164
(87) N° publication PCT/PCT Publication No.: 2006/046052
(30) Priorités/Priorities: 2004/10/26 (GB0423648.5);
2005/02/11 (GB0502849.3); 2005/03/18 (US11/084,356)

(51) Cl.Int./Int.Cl. *G06K 9/00* (2006.01)

(71) Demandeur/Applicant:
FORENSIC SCIENCE SERVICE LIMITED, GB

(72) Inventeur/Inventor:
NEUMANN, CEDRIC, GB

(74) Agent: SIM & MCBURNEY

(54) Titre : ANALYSE ET GENERATION D'IMAGES D'EMPREINTES DIGITALES DEFORMEES
(54) Title: ANALYSING AND GENERATING DISTORTED FINGERPRINT IMAGES

(57) Abrégé/Abstract:
A method of simulating the effect of distortion on a representation of a marker, such as a fingerprint is provided. The method is useful for generating data for use in various processes concerned with fingerprints and particularly avoids the need to manually generate and collect such data. The method includes obtaining a plurality of representations from an individual, the representations being subject to different distortions relative to one another. A function, such as a thin plate spline function, is then used to describe the effects of the different distortions on the plurality of representations obtained. This generic model of the effects of distortion can then be used to generate distortions for a further representation from an individual, preferably another individual. The simulated distorted representations can be used in a variety of ways.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
4 May 2006 (04.05.2006)

PCT

(10) International Publication Number
WO 2006/046052 A1

(51) International Patent Classification:
G06K 9/00 (2006.01)

(21) International Application Number:
PCT/GB2005/004164

(22) International Filing Date: 26 October 2005 (26.10.2005)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

0423648.5	26 October 2004 (26.10.2004)	GB
0502849.3	11 February 2005 (11.02.2005)	GB
11/084,356	18 March 2005 (18.03.2005)	US

(71) Applicant *(for all designated States except US)*: **THE SECRETARY OF STATE FOR THE HOME DEPARTMENT** [GB/GB]; c/o The Forensic Science Service, Priory House, Gooch Street North, Birmingham B5 6QQ (GB).

(72) Inventor; and

(75) Inventor/Applicant *(for US only)*: **NEUMANN, Cedric** [CH/GB]; The Forensic Science Service, Priory House, Gooch Street North, Birmingham B5 6QQ (GB).

(74) Agent: **PAWLYN, Anthony, Neil**; Urquhart-Dykes & Lord LLP, Tower North Central, Merrion Way, Leeds LS2 8PA (GB).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 2006/046052 A1

(54) Title: ANALYSING AND GENERATING DISTORTED FINGERPRINT IMAGES

(57) Abstract: A method of simulating the effect of distortion on a representation of a marker, such as a fingerprint is provided. The method is useful for generating data for use in various processes concerned with fingerprints and particularly avoids the need to manually generate and collect such data. The method includes obtaining a plurality of representations from an individual, the representations being subject to different distortions relative to one another. A function, such as a thin plate spline function, is then used to describe the effects of the different distortions on the plurality of representations obtained. This generic model of the effects of distortion can then be used to generate distortions for a further representation from an individual, preferably another individual. The simulated distorted representations can be used in a variety of ways.

ANALYSING AND GENERATING DISTORTED FINGERPRINT IMAGES

This invention concerns improvements in and relating to comparisons, particularly, but not exclusively to comparisons of biometric markers and the accounting for distortion involved therein.

Various approaches for comparing a biometric marker, such as a fingerprint, from one source with one from another source exist. Some such systems have attempted to account on a case by case basis for the effects of distortion.

The applicant has developed a likelihood ratio based approach for such a comparison and this takes into account the variation in representations of the same finger taken under different conditions.

The present invention has amongst its aims to provide additional data for such a process, without undue burden in its generation.

According to a first aspect of the invention we provide a method of simulating the effect of distortion on a representation of a marker, the method including

obtaining a plurality of representations from an individual, the representations being subject to different distortions relative to one another;

describing the effect of the different distortions on the plurality of representations using a function;

taking a further representation from an individual and preferably another individual, applying the function to that representation to generate one or more simulated distorted representations.

According to a second aspect of the invention we provide a method of forming a data set including distorted representations of a marker, the method including

obtaining a plurality of representations from an individual, the representations being subject to different distortions relative to one another;

describing the effect of the different distortions on the plurality of representations using a function;

taking a further representation from an individual, preferably another individual, applying the function to that representation to generate one or more simulated distorted representations;

adding the one or more simulated distorted representations to a data set.

The first and/or second aspects of the invention may include any of the features, options or possibilities set out elsewhere in this application, including from amongst the following.

The distortion may arise from one or more factors. The factors may be or include the particular finger and/or the particular hand from which the representation arises. The factor may be or include the gender and/or profession and/or height and/or size and/or weight and/or age of the person from whom the representation arises. The factor may be the type and/or material and/or shape of the substrate on which the representation arose.

The marker, preferably a biometric marker, may be a fingerprint, but may be a palm print, ear print, footprint, footwear print or the like.

The plurality of representations may be obtained from the individual under controlled conditions. The conditions may be controlled in terms of the finger used and/or substrate used and/or pressure used and/or extent of distortion used. Preferably one or more repeats of each representation are obtained. Preferably at least 2 repeats and more preferably at least 5 repeats are obtained for each of the different distortions. Preferably at least 5 representations with different distortions are obtained from each individual. Preferably a plurality of representations are obtained from a plurality of individuals. Preferably at least 20 individuals are used, more preferably at least 40.

The function may be or include a non-linear function. The function may be a non-linear transformation. The function may be or include one or more matrices. The function may be defined, at least in part, by a comparison of a pair of the representations having different distortions. The comparison may consider the position of one or more minutiae in each of the representations and/or consider the position of one or more points on one or more ridges. The function may be defined, at least in part, by a thin plate spline approach.

Preferably the method is applied to a plurality of different individuals to provide a plurality of functions. One or more of the functions may be used to generate the simulated distorted representations. One or more of the functions may be combined, for instance to give a composite function. One or more of the functions may be combined to give a general description of distortion. The composite function may be a composite matrix. The

plurality of functions and/or composite function and/or composite matrix may be used to generate one or more simulated distorted representations from a further representation.

The further representation to which the function is applied is preferably an undistorted representation. The representation to which the function is applied may be from a different individual to the individual or individuals that the distorted representations are obtained from. Preferably a plurality of simulated distorted representations are obtained from each representation, potentially nine or more, preferably 10 or more, ideally 25 or more. The function may be used to generate one or more simulated distorted representations for a plurality of individuals, ideally with the same function being used in for each individual.

Preferably the simulated distorted representations are supplied to a data set, ideally a data base.

Preferably the data set and/or data base is used in a comparison method, particularly a comparison method in which a representation being compared is considered against within finger variability and/or between finger variability. The data set and/or data base may be used to form a probability distribution, for instance a probability distribution related to the distance between different representations of the same marker and/or a probability distribution related to the distance between different representations of different markers.

Preferably the data set and/or data base is used in a comparison method, particularly a comparison method in which a test representation from an individual is compared with one or more of the simulated distortions in the data set and/or data base. The comparison may indicate whether there is a match between the test representation and one or more of the simulated distortions. The comparison may indicate whether there is no match between the test representation and one or more, preferably all, the simulated distortions.

The test representation may be from an individual of unknown identity. The test representation may be from a crime scene and/or a location which is investigated as part of a criminal investigation. The location may be a surface, for instance a wall, glass, floor or the like and/or a part of an item, such as a tool, piece of furniture, weapon, glassware or the like.

The further representation from an individual may be stored in a data set and/or data base. The further representation is preferably already in the data set and/or data base

before the test time. The further representation may be stored in the data set and/or data base in the form in which it was taken. This may be an undistorted form. The further representation may have the function applied to that representation to generate one or more simulated distorted representations. These may be generated before and/or during the test time. A plurality of further representations may be present in the data set and/or data base. The data set and/or data base may be contain representations collected, for instance by law enforcement authorities and/or during criminal investigations. The data set and/or data base may be part of an automated fingerprint recognition system or be the data set and/or data base therefrom. The undistorted representations in the data set and/or data base may be distroted prior to their use in the comparison.

The result of the comparison may be used to control a further operation. The further operation may be the opening and/or unlocking and/or movement of an element, for instance a lock and/or door and/or barrier or the like. The test representation may be a representation obtained from an individual at a test time. The comparison may be made at the test time. The one or more simulated distortions and/or the data set and/or database containing them may be generated in advance of the test time. The test time may be a period of 5 minutes or less. The generation in advance may be at least 10 minutes in advance of the start of the test time. The comparison is preferably of the test representation in a distorted form with the one or more simulated distortions. The individual from whom the test representation is obtained is preferably different to the individual from whom the further representation is taken, and is ideally different from an of the individuals from whom further representations are taken.

The method may be repeated for one or more different types and/or direction of distortion. The one or more different types of distortion may include: distortion of and/or towards one end, for instance a top, of a representation; and/or distortion of and/or towards another end, for instance a bottom, of a representation; and/or distortion of and/or towards another end, for instance one side, of a representation; and/or distortion of and/or towards another end, for instance another side, of a representation.

One or more functions may be provided. One or more functions related to or specific to the finger which was the source of the representation may be used, for instance where the finger is the thumb, first finger, index finger, third finger or fourth finger. One or more functions related to or specific to the hand which was the source of the representation may be used, for instance where the hand is the right hand or left hand. One

or more functions related to or specific to the gender of the person who was the source of the representation may be used, for instance where the gender is male or female. One or more functions related to or specific to the size of the person who was the source of the representation may be used, for instance in respect of one or more hyped ranges for the person. One or more functions related to or specific to the age of the person who was the source of the representation may be used, for instance with respect to one or more age ranges. One or more functions related to or specific to the weight of the person who was the source of the representation may be used, for instance with respect to one or more weight ranges. One or more functions related to or specific to the profession of the person who was the source of the representation may be used.

According to a third aspect of the present invention we provide a method of analysing a representation of a marker, the method including

obtaining a representation of a marker from a location;

processing the representation by applying a function to the representation to generate one or more revised representations, the function being obtained by a method including:

obtaining a plurality of representations from an individual, the representations being subject to different distortions relative to one another; and

describing the effect of the different distortions on the plurality of representations using a function;

comparing the one or more revised representations with one or more existing representations to analyse the representation of a marker for a match with one or more existing representations and/or a lack of a match with one or more existing representations.

The various features, options and possibilities set out elsewhere in this application, and in particular in the first and/or second aspects, are applicable to the third aspect also.

The representation of the marker may be from an unidentified individual. The representation may be obtained from a location which is a crime scene and/or a location which is investigated as part of a criminal investigation. The location may be a surface, for

instance a wall, glass, floor or the like and/or a part of an item, such as a tool, piece of furniture, weapon, glassware or the like.

The representation to which the function is applied is preferably a distorted representation. The representation to which the function is applied may be from an unknown individual.

The function may be used to generate one or more revised representations which are, or are closer to being, an undistorted revised representation than the representation. The function may generate one or more revised representations which are less distorted than the representation. The function may also generate one or more revised representations which are more distorted than the representation and/or distorted in different ways compared with the representation.

The comparing of the one or more revised representations with one or more existing representations may establish one or more matches. A match may be declared where a revised representation and an existing representation have a measure of similarity above a threshold. A match may be used as evidence of a link between the individual who is the source of the representation with the individual who is the source of the existing representation to which there is a match. A match may be used as evidence of a link between the individual who is the source of the representation and the location from which the existing representation was obtained. A match may be used as evidence in a court of law. A match may be used to control further analysis and/or investigations.

The comparing of the one or more revised representations with one or more existing representations may establish one or more mis-matches. A mis-match may be declared where a revised representation and an existing representation have a measure of similarity below a threshold.

The one or more existing representations may be provided by one or more data bases. One or more of the databases may include representations of markers from known individuals and/or known locations.

According to a fourth aspect of the present invention we provide a method of analysing a representation of a marker, the method including

obtaining a representation of a marker from a location;

providing one or more existing representations of a marker;

processing one or more of the existing representation by applying a function to the existing representation to generate one or more revised existing representations, the function being obtained by a method including:

obtaining a plurality of representations from an individual, the representations being subject to different distortions relative to one another; and

describing the effect of the different distortions on the plurality of representations using a function;

comparing the representation with one or more of the revised existing representations to analyse the representation of a marker for a match with one or more of the revised existing representations and/or a lack of a match with one or more of the revised existing representations.

The various features, options and possibilities set out elsewhere in this application, and in particular in the first and/or second aspects, are applicable to the fourth aspect also.

The representation of the marker may be from an unidentified individual. The representation may be obtained from a location which is a crime scene and/or a location which is investigated as part of a criminal investigation. The location may be a surface, for instance a wall, glass, floor or the like and/or a part of an item, such as a tool, piece of furniture, weapon, glassware or the like.

The existing representation to which the function is applied is preferably a non-distorted representation. The representation to which the function is applied may be from a known individual.

The function may be used to generate one or more revised existing representations which are, or are closer to being, the representation than the existing representation. The function may generate one or more revised existing representations which are more distorted than the representation. The function may also generate one or more revised existing representations which are less distorted than the representation and/or distorted in different ways compared with the representation.

The comparing of the one or more revised existing representations with the representation may establish one or more matches. A match may be declared where a revised existing representation and the representation have a measure of similarity above a

threshold. A match may be used as evidence of a link between the individual who is the source of the representation with the individual who is the source of the existing representation to which there is a match. A match may be used as evidence of a link between the individual who is the source of the representation and the location from which the existing representation was obtained. A match may be used as evidence in a court of law. A match may be used to control further analysis and/or investigations.

The comparing of the one or more revised existing representations with the representation may establish one or more mis-matches. A mis-match may be declared where a revised existing representation and the representation have a measure of similarity below a threshold.

The one or more existing representations may be provided by one or more data bases. One or more of the databases may include representations of markers from known individuals and/or known locations. The data base may be part of and/or be from and/or be extracted from an automated fingerprint recognition system.

Various embodiments of the present invention will now be described, by way of example only.

The comparison of fingerprints, or other biometric markers, obtained from one source with those obtained from another source is useful for a variety of purposes, including in forensic science. In the forensic science context, the comparison may seek to suggest that a representation of a finger mark from a crime scene is linked to a suspect.

The applicant has conducted research and developed an approach which seeks to evaluate the strength of the link between a crime scene representation of a fingerprint and a representation of a fingerprint taken from a suspect and to present this evidence using a likelihood approach. A significant issue in this approach and in other approaches to the consideration of representations of fingerprints is the issue of distortion.

Whilst a suspect's print taken in a controlled manner, using preferred materials, is fairly consistent in terms of the representation it gives between occasions, this is not the case in crime scene cases. Representations of fingerprints left during day to day activities, including those which are then associated with a crime, arise under a wide variety of conditions. The pressure applied, movement during application, the substrate involved and

a variety of other factors can all alter the form of the representation which arises when compared with others left or with representations taken under controlled conditions.

In the approach taken by the applicant, detailed in applicant's UK patent application number GB0422784.9 filed 14 October 2004 and/or UK patent application number GB 0502900.4 filed 11 February 2005, the representations of interest are considered in the context of two data sets. A data set representative of the variation in representations of fingerprints across the population (say based on 2000 fingerprints) and a data set representative of the variation in representations of the same fingerprint with specific distortion are used. The existing data set representative of the variation in the representations of the same fingerprint with distortion has been compiled by taking a fingerprint from a small number of individuals (say 4) and obtaining a number of representations for them under a number of specific different conditions (say 9) with a number of repeats for each (say 5). In order to ensure that the different individuals are considered under the same variations in conditions, an extremely time consuming and rigorous procedure is followed. In practical terms this limits the number of different individuals and number of different conditions for each which can be considered.

Instead of physically sampling a large number of individuals, under various conditions and with repeats thereof, the alternative approach of the present invention simulates a large number of specific distorted representations from an undistorted representation. The undistorted representation is easy to collect or could even be obtained from one of a number of existing data sets of such representations. The actual generation of the specific distorted representations is performed by a computer and so is quick to perform on a large scale. The simulation is repeated on a large number of undistorted representations.

Using such an approach, the data set representative of the variation in representations of the same fingerprint with distortion can be increased substantially in size with only a reasonable input effort. This means that the approach and statistical models which use this data set are more robust as a result, as more extensive testing and validation is possible. An additional benefit comes from the approach enabling the creation of very large data sets of distorted representations without the need for physical sampling. A powerful research resource results.

To be able to distort undistorted representations in an appropriate way, it is necessary to derive an appropriate description of the distortion process. To do this, the

approach involves an initial investment in further physical representations of distortion. A significant number of individuals, for instance 40, are used to provide a significant number of distorted representations of their fingerprints, for instance 50 each. For each individual, their representations and the distortion of them are then described using a non-linear mathematical transformation. Such an approach is more accurate than some prior approaches as the nature of the distortion itself is non-linear. In the preferred form the approach establishes a matrix which describes the distortion. An example of such a matrix description of distortion is to be found in *Ross et al., Proceedings of the International Conference on Biometric Authentication (ICBA) Hong Kong, July 2004 "Estimating Fingerprint Deformation"* the contents of which are incorporated herein by reference.

Starting with a pair of representations, these are presented in a black and white format, preferably skeletonised and subjected to appropriate cleaning and healing of the representation. The minutiae locations are then determined and information on them collected for each representation using a suitable information format. The location in the representation and orientation of the associated ridge and grayscale intensity of pixels in the vicinity may be captured in this way. The degree of correspondence between minutiae in the two representations can then be obtained and quantified using one or more techniques, such as an elastic stringer matcher. Ridge curves can be extended from these points and the degree of correspondence between points on the curves established too.

The global effect of different distortions between the different representations on these points is then considered. The Thin Plate Spline approach describes the dependence of point positions on a thin metal plate with the physical bending energy applied to the thin metal plate. The Thin Plate Spline approach is a parametric generalisation from rigid to mild non-rigid deformations. The parameters of the Thin Plate Spline approach can be obtained from a matrix equation and various approaches to the solution of the equation can be taken. An average deformation model can be obtained from the technique.

In the Ross et al., paper, a number of representations of a marker of a particular individual are taken. These are taken under generally similar but uncontrolled conditions and so reflect the common extent of variation for that marker of that individual. The results are used to form the average deformation model for that individual. The average deformation model can be considered as modelling the behaviour of the individual. The average deformation model is used to distort the representation or "baseline impression" of a particular individual before that is compared with the other, template representation of a

particular individual. As a result, the comparison process is improved. No use of the distorted representation is made outside of the one representation versus another representation comparison for a particular individual. If another individual is to be considered, then representations must be collected for him, an average deformation model for that individual must be generated and that individual's own average deformation model is used in any comparison. Each model is individual specific, therefore, and the model for one individual may be very different to the model for another.

In contrast, the present approach uses the description of specific distortion provided by the matrix and takes it in an alternative direction. Firstly, it differs in terms of the end use as that is to take undistorted representations, which are not involved in any authentication process, and deliberately convert them to distorted representations. These representations are then used together with other such distorted representations to form a data-set, and ideally to contribute to or validate the data set or probability distribution used in the technique of GB0422784.9 filed 14 October 2004 and/or GB0502900.4 filed 11 February 2005. This is a use and interest not involved in the *Ross et al.,* process.

Secondly, the approach differs because the matrix arrived at for specific distortion of an individual is considered together with the matrices arrived at from corresponding distortions of a number of other individuals so as to provide a composite matrix descriptive of distortion in a more general sense. The model of deformation is not specific to an individual, therefore, but instead is applicable between individuals. The modelling of distortion according to the invention can address distortion as a whole, but more preferably a number of different models to cover different directions of distortion are generated. For instance, a model for distortion of the top of the representation can be determined and/or a model for distortion to one side and/or another and/or the bottom can be determined. The models can be used individually and/or together.

The composite matrix which results provides a detailed and appropriate expression of how specific distortion alters representations in general. As such, it is then possible to take an undistorted representation from an individual, who has not provided distorted representations which have been physically collected and considered, and simulate a series of distorted representations for that representation. Repeat uses of the distortion matrix gives repeat distorted representations. All these are useful in terms of contributions to the data set on between representation variability for the same finger

and/or person. The approach can equally well be applied to a set of ten representations collected with one representation for each finger of the person.

Whilst a number of non-linear mathematical transformations are possible, and a number of matrix based approaches are possible, the preferred matrix form is achieved using a Thin Plate Spline approach referenced above. Many variations on that particular way of describing the distortion are possible, however.

Whilst the approach is described above in the context of one, preferably composite, matrix, it is possible to develop a range of such matrices which are expressions of distortion under various conditions. Thus a matrix for each gender and/or hand possible for the person from whom the representation arises is possible. A series of matrices, with individual matrices for different ages of the person from whom the representation arises, is possible. A series of matrices, with individual matrices for different weights of the person from whom the representation arises, is possible. A series of matrices, with individual matrices for different professions of the person from whom the representation arises, is possible.

By way of validation, it is possible to take one or more representations under controlled conditions and apply the distortion matrix to them. The resulting distorted representations can then be compared with real representations obtained under a variety of conditions and hence subject to distortion of their own.

As well as providing a series of distorted representations for one or more individuals, through simulation, so as to populate the data sets used in the comparison process discussed above, the approach can be put to other uses too. In this respect it is possible to use the general deformation model to establish a set of distorted representations for an individual from a control representation. This set then forms a pool of representations against which attempt can be made to match a further representation from that individual taken at another time. A match may be used to authorize entry through a control barrier or the like.

By generating the pool in advance, the system may be able to establish the answer to the match or non-match question quicker than if the further representation needs to be considered for potential effects of distortion before trying to match it with the undistorted control representation.

The general deformation model obtained from the same individual may be used, but it is preferred to use a composite general deformation model obtained by considering a

plurality of individuals, who may or may not include the particular individual being considered. This approach represents another use of a data set quickly generated by the present invention.

The same general approach can be useful in the consideration of markers, such as fingerprints, from crime scenes. The fingerprint obtained from a crime scene is generally a distorted one. This needs to be compared with records, such as a data base, of fingerprints which were collected under other conditions. Where these fingerprints were taken from indivduals under controlled circumstances then these fingerprints are not distorted. Before running a comparison process between the crime scene fingerprint and the data base fingerprint, the general model of distortion can be used to distort the data base fingerprints. The data base considered in this way may include data from existing data bases, such as the data bases available as a component for or within automated fingerprint recognition systesm, AFIS.

By modifying the general approach discussed above, a number of other possibilities are opened up as well.

Firstly, it is possible to take a representation of a fingerprint from a crime scene and provide an improved chance of being able to match it to another fingerprint. Thus the crime scene representation could be entered into a computer system and then have the description of specific distortion provided by the matrix applied to it in reverse. By doing so a multiple of times it is likely that one of these applications will result in an undistortion which matches the distortion which occurred when the crime scene representation was created. In effect, an undistorted version of the crime scene representation is obtained.

This undistorted representation can then be searched against databases of existing fingerprints which have been collected. A match may provide an indication of a link between the crime scene representation processed by undistorting it and another fingerprint from a known individual and/or other crime scene or the like. A match would be unlikely to occur if the distorted representation direct from the crime scene were compared with the database. This information on a match can be useful evidence in itself and/or be useful in directing further law enforcement investigations or the collection of further evidence.

The use of the above mentioned Thin Plate Spline approach is particularly useful in this regard.

CLAIMS

1. A method of simulating the effect of distortion on a representation of a marker, the method including

obtaining a plurality of representations from an individual, the representations being subject to different distortions relative to one another;

describing the effect of the different distortions on the plurality of representations using a function;

taking a further representation from an individual and preferably another individual, applying the function to that representation to generate one or more simulated distorted representations.

2. A method according to claim 1 in which the function is or includes a non-linear function.

3. A method according to claim 2 in which the function is a non-linear transformation.

4. A method according to claim 1 in which the function is or includes one or more matrices.

5. A method according to claim 1 in which the function is defined, at least in part, by a comparison of a pair of the representations having different distortions.

6. A method according to claim 5 in which the comparison considers the position of one or more minutiae in each of the representations and/or considers the position of one or more points on one or more ridges.

7. A method according to claim 1 in which the function is defined, at least in part, by a thin plate spline approach.

8. A method according to claim 1 in which the plurality of representations are obtained from the individual under controlled conditions.

9. A method according to claim 8 in which the conditions are controlled in terms of the finger used and/or substrate used and/or pressure used and/or extent of distortion used.

10. A method according to claim 1 in which one or more repeats of each representation are obtained.

11. A method according to claim 1 in which a plurality of representations are obtained from a plurality of individuals.

12. A method according to claim 1 in which the method is applied to a plurality of different individuals to provide a plurality of functions.

13. A method according to claim 12 in which the two or more of the functions are combined to give a composite function.

14. A method according to claim 12 in which two or more of the functions are combined to give a general description of distortion.

15. A method according to claim 12 in which the plurality of functions and/or composite function are used to generate one or more simulated distorted representations from a further representation.

16. A method according to claim 1 in which the function is applied to a further representation to generate one or more simulated distorted representations from a further representation.

17. A method according to claim 16 in which the further representation to which the function is applied being an undistorted representation.

18. A method according to claim 16 in which the representation to which the function is applied is from a different individual to the individual or individuals that the distorted representations are obtained from.

19. A method according to claim 16 in which a plurality of simulated distorted representations are obtained from each representation.

20. A method according to claim 16 in which the function is used to generate one or more simulated distorted representations for a plurality of individuals, with the same function being used in for each individual.

21. A method according to claim 16 in which the simulated distorted representations are supplied to a data set.

22. A method according to claim 21 in which the data set is used in a comparison method in which a representation being compared is considered against within finger variability and/or between finger variability.

23. A method according to claim 21 in which the data set is used to form a probability distribution.

24. A method according to claim 23 in which a probability distribution relates to the distance between different representations of the same marker and/or in which a probability distribution relates to the distance between different representations of different markers.

25. A method according to claim 1 in which the method is repeated for one or more different types and/or directions of distortion.

26. A method according to claim 1 in which the distortion arises from one or more of the following factors: the particular finger from which the representation arises, the particular hand from which the representation arises, the gender of the person from whom the representation arises, the profession of the person from whom the representation arises, the height of the person from whom the representation arises, the size of the person from whom the representation arises, the weight of the person from whom the representation arises, the age of the person from whom the representation arises, the type of the substrate on which the representation arose, the material of the substrate on which the representation arose, the shape of the substrate on which the representation arose.

27. A method of forming a data set including distorted representations of a marker, the method including

obtaining a plurality of representations from an individual, the representations being subject to different distortions relative to one another;

describing the effect of the different distortions on the plurality of representations using a function;

taking a further representation from an individual, preferably another individual, applying the function to that representation to generate one or more simulated distorted representations;

adding the one or more simulated distorted representations to a data set.

28. A method of analysing a representation of a marker, the method including

obtaining a representation of a marker from a location;

processing the representation by applying a function to the representation to generate one or more revised representations, the function being obtained by a method including:

obtaining a plurality of representations from an individual, the representations being subject to different distortions relative to one another; and

describing the effect of the different distortions on the plurality of representations using a function;

comparing the one or more revised representations with one or more existing representations to analyse the representation of a marker for a match with one or more existing representations and/or a lack of a match with one or more existing representations.

29. A method according to claim 28 in which the representation is from an individual of unknown identitity and one or more of the existing representations are from individuals of known identity.

30. A method according to claim 28 or claim 30 in which a match is used as evidence of a link between the individual who is the source of the representation with the individual who is the source of the existing representation to which there is a match and/or a match is used as evidence of a link between the individual who is the source of the representation

and the location from which the existing representation was obtained and/or a match is used as evidence in a court of law and/or a match is used to control further analysis and/or investigations by or on behalf of a law enforcement authority.