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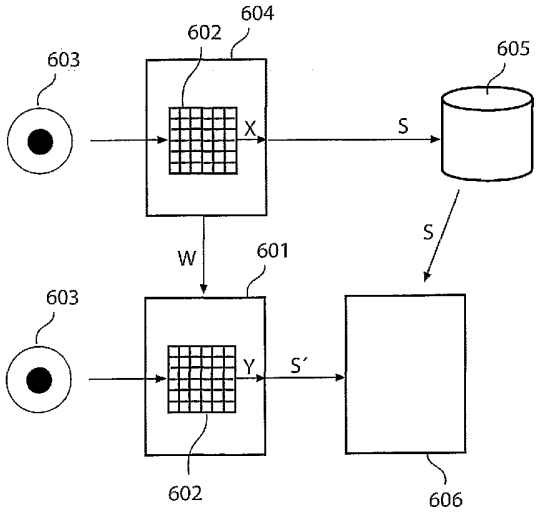
(54) Title: ARCHITECTURES FOR PRIVACY PROTECTION OF BIOMETRIC TEMPLATES



(57) Abstract: The present invention relates to a system and a method of verifying the identity of an individual by employing biometric data associated with the individual (603), wherein privacy of said biometric data (X, Y) is provided. A helper data scheme (HDS) is employed to provide privacy of the biometric data. The present invention is advantageous for number of reasons. First, processing of security sensitive information is performed in a secure, tamper-proof environment (601, 604, 606) which is trusted by the individual. This processing, combined with utilization of a helper data scheme, enables set up of a biometric system where the biometric template is available in electronic form only in the secure environment. Moreover, electronic copies of the biometric templates are not available in the ecure environment permanently, but only when the individual offers her template to the sensor.

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Architectures for privacy protection of biometric templates

The present invention relates to a system and a method of verifying the identity of an individual by employing biometric data associated with the individual, wherein privacy of said biometric data is provided.

Authentication of physical objects may be used in many applications, such as conditional access to secure buildings or conditional access to digital data (e.g. stored in a computer or removable storage media), or for identification purposes (e.g. for charging an identified individual for a particular activity).

The use of biometrics for identification and/or authentication is to an ever-increasing extent considered to be a better alternative to traditional identification means such as passwords and pin-codes. The number of systems that require identification in the form of passwords/pin-codes is steadily increasing and, consequently, so is the number of passwords/pin-codes which a user of the systems must memorize. As a further consequence, due to the difficulty in memorizing the passwords/pin-codes, the user writes them down, which makes them vulnerable to theft. In the prior art, solutions to this problem have been proposed, which solutions involve the use of tokens. However, tokens can also be lost and/or stolen. A more preferable solution to the problem is the use of biometric identification, wherein features that are unique to a user such as fingerprints, irises, ears, faces, etc. are used to provide identification of the user. Clearly, the user does not lose or forget his/her biometric features, neither is there any need to write them down or memorize them.

The biometric features are compared to reference data. If a match occurs, the user is identified and can be granted access. The reference data for the user has been obtained earlier and is stored securely, e.g. in a secure database or smart card. In authentication, the user claims to have a certain identity and an offered biometric template is compared with a stored biometric template that is linked to the claimed identity, in order to verify correspondence between the offered and the stored template. In identification, the offered biometric template is compared with all stored available templates, in order to verify

correspondence between the offered and stored template. In any case, the offered template is compared to one or more stored templates.

Whenever a breach of secrecy has occurred in a system, for example when a hacker has obtained knowledge of secrets in a security system, there is a need to replace the (unintentionally) revealed secret. Typically, in conventional cryptography systems, this is done by revoking a revealed secret cryptographic key and distributing a new key to the concerned users. In case a password or a pin-code is revealed, it is replaced by a new one. In biometric systems, the situation is more complicated, as the corresponding body parts obviously cannot be replaced. In this respect, most biometrics are static. Hence, it is important to develop methods to derive secrets from (generally noisy) biometric measurements, with a possibility to renew the derived secret, if necessary. It should be noted that biometric data is a good representation of the identity of an individual, and unauthenticated acquirement of biometric data associated with an individual can be seen as an electronic equivalent of stealing the individual's identity. After having acquired appropriate biometric data identifying an individual, the hacker may impersonate the individual whose identity the hacker acquired. Moreover, biometric data may contain sensitive and private information on health conditions. Hence, the integrity of individuals employing biometric authentication/identification systems must be safeguarded.

As biometrics provide sensitive information about an individual, there are privacy problems related to the management and usage of biometric data. For example, in prior art biometric systems, a user must inevitably trust the biometric systems completely with regard to the integrity of her biometric template. During enrolment – i.e. the initial process when an enrolment authority acquires the biometric template of a user - the user offers her template to an enrolment device of the enrolment authority which stores the template, possibly encrypted, in the system. During verification, the user again offers her template to the system, the stored template is retrieved (and decrypted if required) and matching of the stored and the offered template is effected. It is clear that the user has no control of what is happening to her template and no way of verifying that her template is treated with care and is not leaking from the system. Consequently, she has to trust *every* enrolment authority and *every* verifier with the privacy of her template. Although these types of systems are already in use, for example in some airports, the required level of trust in the system by the user makes widespread use of such systems unlikely.

Cryptographic techniques to encrypt or hash the biometric templates and perform the verification (or matching) on the encrypted data such that the real template is

never available in the clear can be envisaged. However, cryptographic functions are intentionally designed such that a small change in the input results in a large change in the output. Due to the very nature of biometrics and the measurement errors involved in obtaining the offered template as well as the stored template due to noise-contamination, the offered template will never be exactly the same as the stored template and therefore a matching algorithm should allow for small differences between the two templates. This makes verification based on encrypted templates problematic.

In Match on Card (MoC) systems as described in e.g. "The Match On Card Technology" by Magnus Pettersson, White paper 22 August 2001, a biometric template is stored on a smart card that also has a fingerprint sensor. During verification, a user presents her biometric template (e.g. a fingerprint) to the sensor and the card determines if there is a match between the stored and offered template. The result of the comparison is sent to a verifier. One advantage of this approach is that no templates are centrally stored. However, a biometric template is still stored permanently in the system and if the smart card is lost, an attacker might obtain the template by manipulating the smart card. Although the template is stored in encrypted form and decrypted prior to performing template matching in the card, proper management of the decryption key presents new privacy problems. Further, the verifier has to trust the card completely in the sense that the template matching is completely performed in the card and the verifier is presented with a match confirmation. This may considerably decrease the chances that verifiers will accept the system.

It is an object of the present invention to provide a biometric system for authentication and/or identification which a user can trust in that the system does not store the biometric template of the user. Hence, privacy of the biometric template is provided.

This is attained by a system for verifying the identity of an individual by employing biometric data associated with the individual, which system provides privacy of said biometric data, in accordance with claim 1 and a method of verifying the identity of an individual by employing biometric data associated with the individual, which method provides privacy of said biometric data in accordance with claim 13.

According to a first aspect of the present invention, there is provided a system comprising a verifier, a secure, tamper-proof user device which is trusted by the individual, an enrolment authority and a central storage, wherein the enrolment authority is arranged to store enrolment data at said central storage, the enrolment data being secret and based on a

first set of biometric data of the individual. The user device is arranged to receive a second set of biometric data of the individual, to generate secret verification data based on said second set of biometric data and helper data, which helper data is based on the first set of biometric data and related to the enrolment data, and the verifier is arranged to acquire the enrolment data from the central storage, to acquire verification data from the user device and to compare the enrolment data with the verification data to check for correspondence, wherein the identity of the individual is verified if correspondence exists.

According to a second aspect of the present invention, there is provided a method that comprises the steps of acquiring enrolment data, the enrolment data being secret and based on a first set of biometric data of the individual, acquiring verification data that is secret and based on a second set of biometric data of the individual and helper data, which helper data is based on the first set of biometric data of the individual and related to the enrolment data and comparing the enrolment data with the verification data to check for correspondence, wherein the identity of the individual is verified if correspondence exists. Further, processing of the biometric data of the individual, the enrolment data and the verification data is performed in a secure, tamper-proof environment which is trusted by the individual.

A basic idea of the invention is that biometric data of individuals should not be stored in biometric systems, in order to provide privacy and to avoid identity-revealing attacks on the biometric systems. By solving security-related problems concerning biometrics, the acceptance level for biometric identification will increase. In biometric systems, the identity of an individual must be verified depending on the actual purpose of the particular biometric system. Different biometric systems typically have differing purposes for verifying the identity of an individual. For example, one system may provide conditional access to secure buildings or conditional access to digital data (e.g. stored in a computer or removable storage media), whereas another system is employed for identification purposes (e.g. used for charging the identified person for a particular activity). Note that when verification of an individual's identity is performed in the present invention, this verification may imply that authentication of an individual is performed or that identification of an individual is performed. In authentication, the individual claims to have a certain identity and offered data based on a biometric template is compared with stored data (linked to the claimed identity) based on the biometric template, in order to verify correspondence between the offered and stored data. In identification, the offered data is compared with a plurality of stored available data sets, in order to verify correspondence between the offered and stored

data. In any case, the offered data is compared to one or more stored data sets. It is clear that the term "verification" may denote either "authentication" or "identification" throughout the application, depending on the context in which the term is used.

When verification is to be performed, a verifier must in some way acquire data that allows the verifier to identify or authenticate an individual. For example, the verifier may actively fetch verification data from a central storage, or passively receive the verification data from the storage. In either case, the verifier acquires enrolment data from the central storage. The enrolment data is secret (to hamper impersonation attacks) and based on a first set of biometric data of the individual. This enrolment data is extracted from the first set of biometric data during an enrolment phase which must be performed in a secure, tamper-proof environment which is trusted by the individual, such that the enrolment data or the biometric data of the individual is not revealed. In the secure environment, it is possible that different sets of enrolment data are extracted from one set of biometric data.

Further, the verifier acquires verification data, which verification data also is secret and based on a second set of biometric data of the individual and helper data. This second set of biometric data is provided by the individual in a verification phase and will typically not be identical to the first set of biometric data that is obtained from the individual during the enrolment phase, even though an identical physical property, for example the iris of the individual, is employed. This is for example due to the fact that when the physical property is measured, there is always random noise present in the measurement, so the outcome of a quantization process to convert an analog property into digital data will differ for different measurements of the same physical property. This may also be due to misalignment of the physical property that is measured or elastic distortion. In order to provide robustness to noise, the secure environment derives the helper data which will be used during verification to achieve noise robustness. Since the helper data is centrally stored, it is considered to be public data. In order to prevent impersonation, the enrolment data derived from the biometric data is statistically independent of the helper data. The helper data is arranged such that unique data can be derived from the biometric data of an individual during the verification as well as during the enrolment.

The helper data W and the enrolment data S are based on the first set of biometric data X of the individual via some appropriate function or algorithm F_G so we have $(W, S) = F_G(X)$. Function F_G might be a randomized function which enables generation of many pairs (W, S) of helper data W and enrolment data S for one single biometric template

X. This allows the enrolment data S (and hence also the helper data W) to be different for different enrolment authorities.

The helper data is based on the enrolment data and the first set of biometric data of the individual in that the helper data is chosen such that, when a delta-contracting function is applied to the first set of biometric data and the helper data, the outcome equals the enrolment data. The delta-contracting function has the characteristic that it allows the choice of an appropriate value of the helper data such that any value of biometric data which sufficiently resembles the first set of biometric data results in the same output value, i.e. data which is identical to the enrolment data. As a consequence, G(X, W) = G(Y, W) = S, if Y resembles X to a sufficient degree. Hence, the second set of biometric data will, together with the helper data, result in an output which is identical to the enrolment data. Conversely, substantially different biometric data input to the delta-contracting function will result in different outputs. Hence, the helper data is arranged such that, by means of employing the delta-contracting function to the helper data and the second set of biometric data, the verification data equals the enrolment data with very high probability. Moreover, the helper data is arranged such that no information about the enrolment data is revealed by studying the helper data. Note that the creation of the verification data during the verification must be performed in a secure, tamper-proof environment which is trusted by the individual, such that the verification data or the biometric data (i.e. the second set of biometric data) of the individual is not revealed.

Finally, the enrolment data is compared at the verifier with the verification data to check for correspondence. If the enrolment data is identical to the verification data, the verification of the identity of the individual is successful and the biometric system can act accordingly, for example by giving the individual access to a secure building.

The present invention is advantageous for a number of reasons. First, processing of security sensitive information is performed in a secure, tamper-proof environment which is trusted by the individual. This processing, combined with utilization of a helper data scheme, enables set up of a biometric system where the biometric template is available in electronic form *only* in the secure environment, which typically comes in the form of a tamper-resistant user device employed with a biometric sensor, e.g. a sensor-equipped smart card. Moreover, electronic copies of the biometric templates are not available in the secure environment *permanently*, but only when the individual offers her template to the sensor. After having derived the enrolment data and the helper data, the biometric data is discarded. This is also true for the biometric data obtained in the verification phase; after

having derived the verification data by employing the second set of biometric data, the second set is discarded. This way, in contrast to traditional MoC systems, privacy of the biometric template is maintained even if the secure environment is compromised.

According to an embodiment of the present invention the central storage is arranged to store the helper data and the verifier is arranged to acquire the helper data from the central storage and send it to the user device. If the helper data is stored centrally, the data can be generated either at the user device or at the enrolment authority. Another advantage of having the helper data stored centrally is that all verifiers can be given access to verification data at one single storage. In case the helper data is generated at the user device, the helper data should preferably be stored at the central storage passing through the enrolment authority.

According to another embodiment of the present invention, the user device is arranged to derive the first set of biometric data of the individual, to generate the enrolment data and to send the enrolment data to the enrolment authority. Hence, it is not necessary for the individual to offer her template to the enrolment authority. This is advantageous, as the enrolment authority not necessarily is trustworthy. Although the individual may trust her bank to destroy an electronic copy of the template after enrolment, she may not trust a nightclub or an Internet gambling site to do the same. On the other hand, in accordance with another embodiment of the present invention, the enrolment authority is arranged to derive the first set of biometric data of the individual and to generate the enrolment data. This is advantageous, since the authorization of enrolling individuals is not distributed among user devices, but is maintained at the enrolment authority, which may simplify management of the system.

Further features of, and advantages with, the present invention will become apparent when studying the appended claims and the following description. Those skilled in the art realize that different features of the present invention can be combined to create embodiments other than those described in the following. Further, those skilled in the art will realize that other helper data schemes than the scheme described hereinabove may be employed.

A detailed description of preferred embodiments of the present invention will be given in the following with reference made to the accompanying drawings, in which:

Fig. 1 shows an enrolment path of a principal prior art biometric system;

Fig. 2 shows a verification path of a principal prior art biometric system;

Fig. 3 shows a system for verification of an individual's identity using biometric data associated with the individual in accordance with an embodiment of the present invention;

Fig. 4 shows a verification path of a system for verification of an individual's identity using biometric data associated with the individual in accordance with an embodiment of the present invention;

Fig. 5 shows a verification path of a system for verification of an individual's identity using biometric data associated with the individual in accordance with another embodiment of the present invention; and

Fig. 6 shows a system for verification of an individual's identity using biometric data associated with the individual in accordance with yet another embodiment of the present invention.

Fig. 1 shows an enrolment path of a principal prior art biometric system which will be described in the following. In this example, it is presumed that an individual wishes to enroll as a member of a chain of casinos that uses biometric identification (using e.g. the iris 101 of an individual) for access control. The biometric system that is employed is based on a helper data scheme (HDS) as previously described. In order to become a member, the individual has to undergo an enrolment procedure by offering her iris to a sensor 102 arranged in an enrolment device 104 owned by the casino. Although the system uses an HDS by deriving enrolment data S and helper data W in an enrolment processing unit 103 and storing the data in the central storage unit 105, and which system further does not store the biometric template of the individual, it is possible that the enrolment device has been tampered with such that the biometric template X may be eavesdropped. The individual has no way of verifying if the device 104 has been tampered with or not and although a HDS is used, it is still possible that the biometric template leaks from the system, due to manipulation.

Although the enrolment procedure is, in many practical applications, undertaken in a controlled environment which is trusted by the individual, this is not necessarily true for the verification procedure. Turning to Fig. 2, in order to gain access to a casino comprised in the casino chain after the enrolment is completed, the individual has to offer her biometric template Y derived from her iris 201 via a sensor 202 arranged in a

verification device 204. A verification processing unit 203 fetches the helper data W stored in the central storage 205 and computes the verification data S′ by employing a delta-contracting function. Matching unit 206 compares S with S′, and if there is a match, the identity of the individual has been verified, and the individual is given access to the casino. If there is no match, the individual is not given access to the casino. As in Fig. 1, the system may have been manipulated. The verification device 204 might have been tampered with such that the biometric template Y is eavesdropped and again, the user has no way of controlling the verification procedure.

Fig. 3 shows a system for verification of an individual's identity using biometric data associated with the individual, according to an embodiment of the present invention. The system comprises a user device 301 arranged with a sensor 302 for deriving a first biometric template X from a configuration of a specific physical feature 303 (e.g. a fingerprint, an iris, an ear, a face etc.) of the individual, or even from a combination of physical features. The user device must be secure, tamper-proof and hence trusted by the individual. An enrolment authority 304 initially enrolls the individual in the system by storing enrolment data S in a central storage unit 305, which enrolment data subsequently is used by a verifier 306. The enrolment data S is secret (to avoid identity-revealing attacks by analysis of S) and derived, in the embodiment of Fig. 3 at the user device 301 from the first biometric template X. At the time of verification, a second biometric template Y, which typically is a noise-contaminated copy of the first biometric template X, is offered by the individual 403 to the user device 401 via the sensor 402, see Fig. 4. The user device 401 generates secret verification data (S′) based on the second set Y of biometric data and helper data W. The helper data W is based on the first set X of biometric data relates to and the enrolment data S. The helper data W is typically calculated such that S = G(X, W), where G is a delta-contracting function. Hence, as W and S are calculated from the template X using a function or algorithm F_G such that (W, S) = F_G(X).

The verifier 406 authenticates or identifies the individual by means of the enrolment data S and verification data S′ received from the user device 401. Noise-robustness is provided by calculating verification data S′ at the user device 401 as S′ = G(Y, W). The delta-contracting function has the characteristic that it allows the choice of an appropriate value of the helper data W such that S′ = S, if the second set Y of biometric data sufficiently resembles the first set X of biometric data. Hence, if S′ = S, verification is successful.

In a practical situation, the enrolment authority may coincide with the verifier, but they may also be distributed. As an example, if the biometric system is used for banking applications, all larger offices of the bank will be allowed to enroll new individuals into the system, such that a distributed enrolment authority is created. If, after enrollment, the individual wishes to withdraw money from such an office while using her biometric data as authentication, this office will assume the role of verifier. On the other hand, if the user makes a payment in a convenience store using her biometric data as authentication, the store will assume the role of the verifier, but it is highly unlikely that the store ever will act as enrolment authority. In this sense, we will use the enrolment authority and the verifier as non-limiting abstract roles.

As can be seen hereinabove, the individual has access to a device that contains a biometric sensor and is capable of computing S' = G(Y, W). In practice, the device could comprise a fingerprint sensor integrated in a smart card or a camera for iris or facial recognition in a mobile phone or a PDA. The fact that the individual may own the user device makes it less likely that the device should be tampered with and is easier for the individual to trust. It is assumed that the individual has obtained the device from a trusted authority (e.g. a bank, a national authority, a government) and that she therefore trusts this device.

In an embodiment of the invention, which is illustrated in Fig. 5, the helper data W is stored at the central storage 505 by the enrolment authority (not shown), fetched by the verifier 506 and sent to the user device 501 when verification is to be performed. The user device 501 then uses the helper data W received from the verifier 506 and the second template Y (which is received from the individual 503 via the sensor 502) to calculate the verification data S′. Thereafter, S′ is compared with S at the verifier 506 to check for a match. In an alternative embodiment, the helper data is not stored at the central storage, but at the user device. In that case, it is not necessary that the verifier fetches the helper data and sends it to the user device, since the user device already is in possession of it.

Fig. 6 shows another embodiment of the present invention, in which embodiment the enrolment authority 604 is arranged with a sensor 602 to derive a first biometric template X from a configuration of a specific physical feature 603 of the individual. The enrolment authority 604 stores enrolment data S in a central storage unit 605, which enrolment data subsequently is used by the verifier. The helper data W may be stored in the central storage 605, or alternatively, as shown in Fig. 6, at the user device 601. The verification is performed in the manner described hereinabove; the verifier 606 authenticates or identifies the individual by means of the enrolment data S stored at the central storage 605;

and the verification data S′ received from the user device 601. If S′ = S, verification is successful. It should be noted that the secret enrolment data S and the helper data W is derived at the device with which the enrolment is effected. If the enrolment is effected at the used device as shown in Fig. 3, then the secret enrolment data S and the helper data W is generated at the user device. On the other hand, if the enrolment is effected at the enrolment authority as shown in Fig. 6, then the secret enrolment data S and the helper data W is generated at the enrolment authority. If an enrolment authority generates S and W, the individual will have to offer her template to the enrolment authority, which not necessarily is trustworthy. Although the individual may trust her bank to destroy the electronic copy of the template after enrolment, she may not trust a nightclub or an internet gambling site to do the same.

Communication between devices may be established using any known appropriate communication channel, e.g. a wireless channel employing RF or IR transmission, or a cable employing, for example, a public switched telephone network (PSTN).

Although the helper data W and the enrolment data S are generated either at the user device or the enrolment authority, and stored either at the user device or the verifier in the system described hereinabove, this is not necessarily the case. It is straightforward and obvious to a skilled person to modify the system in accordance with the present invention, such that the helper data W and the enrolment data S are generated partly at the user device and partly at the enrolment authority and may also partly be stored at the user device and partly at the verifier. It is trivial to combine some or all of the described embodiments of the present invention to arrive at such modifications. Further, it is obvious to a skilled person that the data and the communications in the architectures above can be further protected using standard cryptographic techniques such as SHA-1, MD5, AES, DES or RSA. Before any data is exchanged between devices (during enrollment as well as during verification) comprised in the system, a device might want some proof on the authenticity of another other device with which communication is established. For example, during the embodiment described in connection to Fig. 3, it is possible that the enrolment authority must be ensured that a trusted device did generate the enrolment data received. This can be achieved by using public key certificates or, depending on the actual setting, symmetric key techniques. Moreover, in the embodiment of Fig. 3, it is possible that the enrolment authority must be ensured that the user device can be trusted and that it has not been tampered with. Therefore, in many cases, the user device will contain mechanisms that allow the enrolment authority to detect tampering.

For example, Physical Uncloneable Functions (PUFs) may be implemented in the system. A PUF is a function that is realized by a physical system, such that the function is easy to evaluate but the physical system is hard to characterize. Depending on the actual setting, communications between devices might have to be secret and authentic. Standard cryptographic techniques that can be used are Secure Authenticated Channels (SACs) based on public key techniques or similar symmetric techniques.

Also note that the enrolment data and the verification data may be cryptographically concealed by means of employing a one-way hash function, or any other appropriate cryptographic function that conceals the enrolment data and verification in a manner such that it is computationally infeasible to create a plain text copy of the enrolment/verification data from the cryptographically concealed copy of the enrolment/verification data. It is, for example possible to use a keyed one-way hash function, a trapdoor hash function, an asymmetric encryption function or even a symmetric encryption function.

It is clear that the devices comprised in the system of the invention, i.e. the user device, the enrolment authority, the verifier and possibly also the central storage, is arranged with microprocessors or other similar electronic equipment having computing capabilities, for example programmable logic devices such as ASICs, FPGAs CPLDs etc. Further, the microprocessors executes appropriate software stored in memories, on discs or on other suitable media for accomplishing tasks of the present invention.

Even though the invention has been described with reference to specific exemplifying embodiments thereof, many different alterations, modifications and the like will become apparent for those skilled in the art. The described embodiments are therefore not intended to limit the scope of the invention, as defined by the appended claims.

CLAIMS:

1. A system for verifying the identity of an individual by employing biometric data associated with the individual, which system provides privacy of said biometric data, which system comprises:

- a verifier (306);
- a secure, tamper-proof user device (301) which is trusted by the individual;
- an enrolment authority (304); and
- a central storage (305), wherein

said enrolment authority is arranged to store enrolment data (S) at said central storage, the enrolment data (S) being secret and based on a first set (X) of biometric data of the individual (303); said user device is arranged to receive a second set (Y) of biometric data of the individual, to generate secret verification data (S′) based on said second set (Y) of biometric data and helper data (W), said helper data (W) being based on the first set (X) of biometric data and related to the enrolment data (S); and said verifier is arranged to acquire the enrolment data (S) from the central storage, to acquire verification data (S′) from the user device and to compare the enrolment data (S) with the verification data (S′) to check for correspondence, wherein the identity of the individual is verified if correspondence exists.

2. The system according to claim 1, wherein said central storage (505) is arranged to store the helper data (W); and said verifier (506) is arranged to acquire said helper data (W) from the central storage and send said helper data (W) to the user device (501).

3. The system according to claim 2, wherein said user device (301) is arranged to generate the helper data (W) and forward the helper data (W) to the enrolment authority (304), and wherein said enrolment authority is arranged to store the helper data (W) at the central storage (305).

4. The system according to claim 2, wherein said enrolment authority (304) is arranged to generate the helper data (W) and store it in the central storage (305).

5. The system according to claim 1, wherein said user device (401) is arranged to generate the helper data (W) and store it at the user device.

6. The system according to claim 1, wherein said enrolment authority (604) is arranged to generate the helper data (W) and store it at the user device (601).

7. The system according to claim 1, wherein said helper data (W) is generated, and subsequently used in a delta-contracting function.

8. The system according to claims 3 or 5, wherein said user device (301) is arranged to derive the first set (X) of biometric data of the individual (303), to generate the enrolment data (S) and to send the enrolment data (S) to the enrolment authority (304).

9. The system according to claim 8, wherein said user device (301) further is arranged with a sensor (302) for deriving a biometric template (X, Y) from at least one physical feature of the individual (303, 304).

10. The system according to claims 4 or 6, wherein said enrolment authority (604) is arranged to derive the first set (X) of biometric data of the individual (603) and to generate the enrolment data (S).

11. The system according to claim 10, wherein said enrolment authority (604) further is arranged with a sensor (602) for deriving a biometric template (X) from at least one physical feature of the individual (603).

12. The system according to claim 1, wherein the user device (301) comprises a smart card.

13. A method of verifying the identity of an individual by employing biometric data associated with the individual, which method provides privacy of said biometric data, the method comprising the steps of:

- acquiring enrolment data (S), the enrolment data (S) being secret and based on a first set (X) of biometric data of the individual (303);

- acquiring verification data (S′), the verification data (S′) being secret and based on a second set (Y) of biometric data of the individual and helper data (W), said helper data (W) being based on the first set (X) of biometric data of the individual and related to the enrolment data (S); and
- comparing the enrolment data (S) with the verification data (S′) to check for correspondence, wherein the identity of the individual is verified if correspondence exists; wherein processing of the biometric data (X, Y) of the individual, the enrolment data (S) and the verification data (S′) is performed in a secure, tamper-proof environment (301) which is trusted by the individual.

14. The method according to claim 13, further comprising the steps of:
- acquiring said helper data (W); and
- sending said helper data (W) to the secure, tamper-proof environment (301) which is trusted by the individual.

15. The method according to claim 13, further comprising the steps of:
- generating the helper data (W) at the secure, tamper-proof environment (301) which is trusted by the individual; and
- forwarding the helper data (W) to an enrolment authority (304).

16. The method according to claim 14, further comprising the step of:
- generating the helper data (W) at said enrolment authority (304).

17. The method according to claim 13, wherein said helper data (W) is generated, and subsequently used in a delta-contracting function.

18. The method according to claim 15, wherein deriving the first set (X) of biometric data of the individual (303), generating the enrolment data (S) and sending the enrolment data (S) to the enrolment authority is performed at the secure, tamper-proof environment (301) which is trusted by the individual.

19. The method according to claim 16, wherein deriving the first set (X) of biometric data of the individual (603) and generating the enrolment data (S) is performed at said enrolment authority (604).

20. A computer program product comprising executable components for causing a device having computing capabilities to perform the steps recited in claim 13 when the components are executed in said device having computing capabilities.

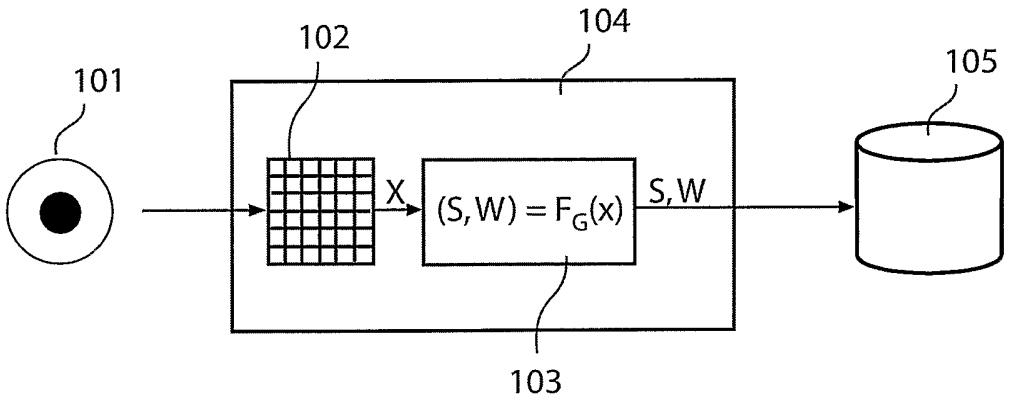
101
102
104
105
X
(S,W) = F_G(x)
S,W
103

Fig. 1

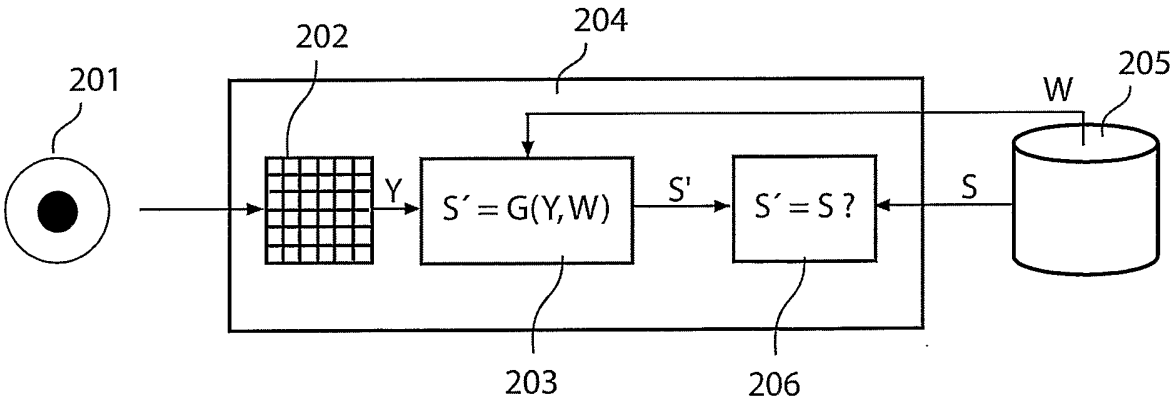
201
202
204
205
W
Y
S´ = G(Y,W)
S'
S´ = S ?
S
203
206

Fig. 2

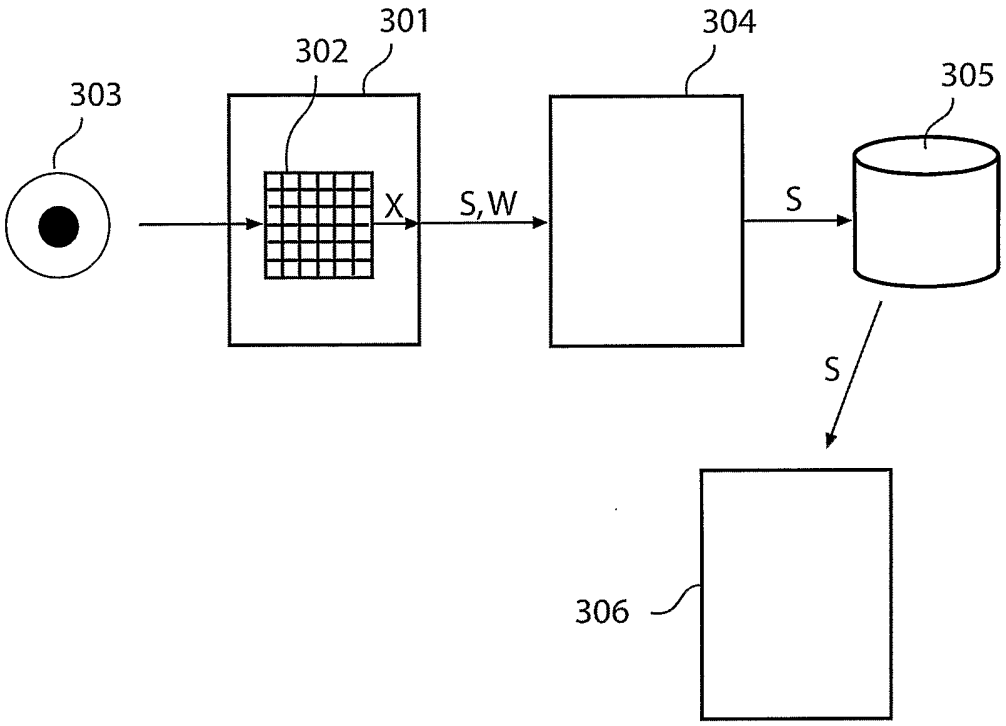

Fig. 3

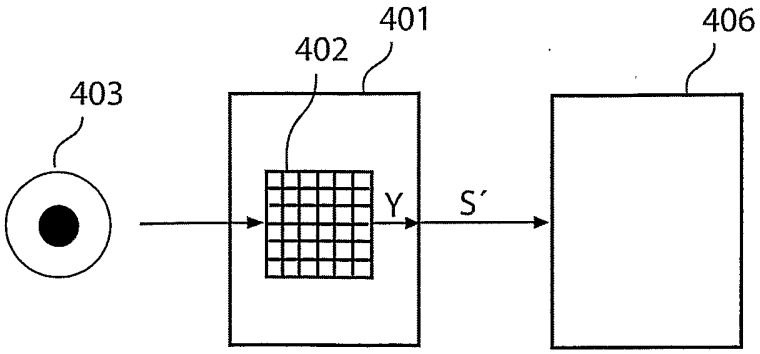

Fig. 4

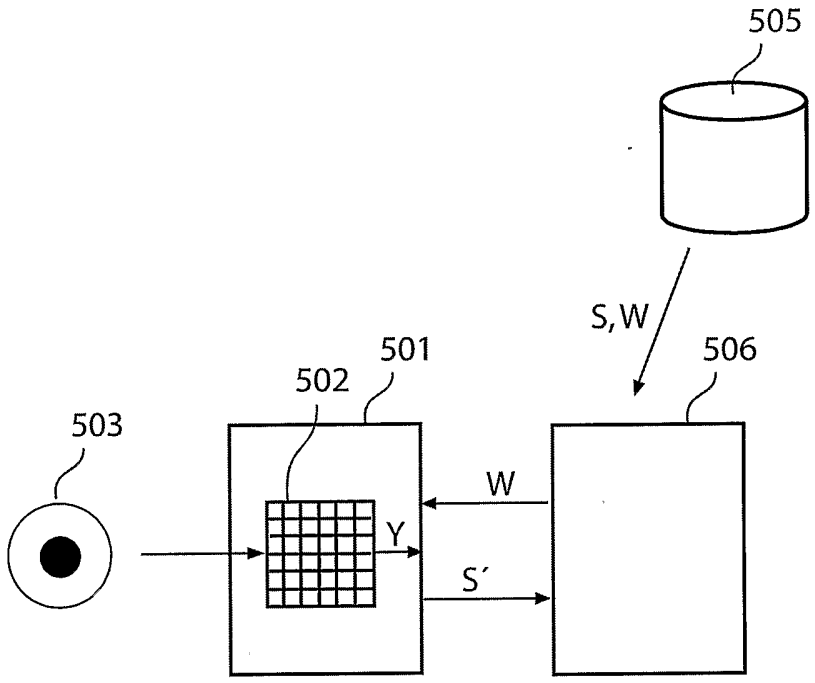
505
S,W
506
501
502
503
W
Y
S´

Fig. 5

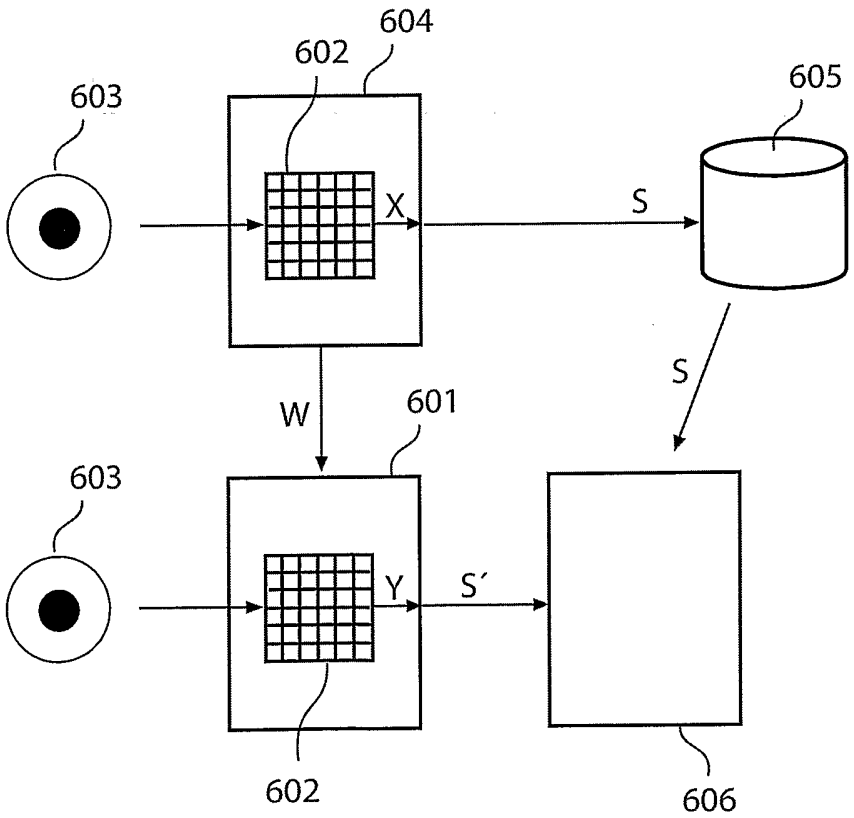
604
602
603
605
X
S
S
W
601
603
Y
S´
602
606

Fig. 6