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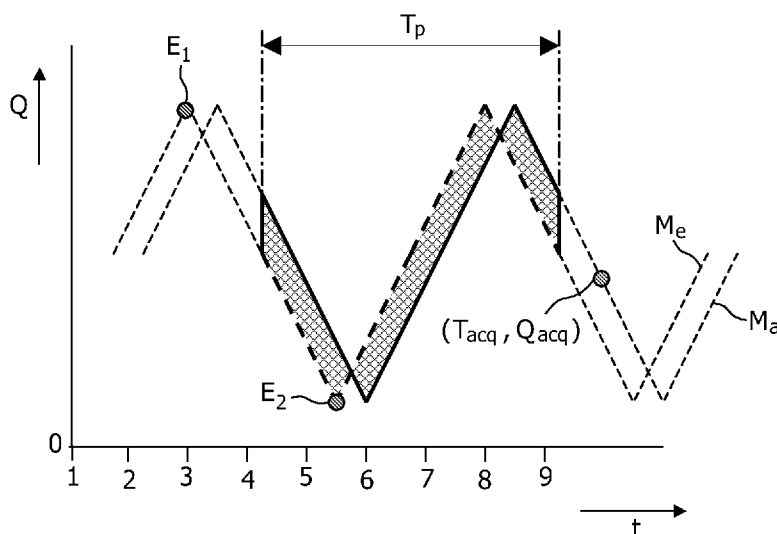
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(54) Title: METHOD AND APPARATUS FOR BIOMETRIC AUTHENTICATION/IDENTIFICATION OF A PERSON



(57) Abstract: The present invention relates to a method of biometric authentication/identification of a person that comprises the step of using a predictable time-variant first physiological characteristic for establishing consistency of a first reference point comprising a first timestamp (803) and a first feature vector (802) of the person being authenticated/identified with a model (Mi) of a reference person and authenticating/identifying the person as the reference person in dependence of the establishing, the first timestamp (803) being the time of authentication/identification of the person, the first feature vector (802) being a feature vector representative of the first physiological characteristic of the person at the first timestamp, the model (Mi) being a model of a feature vector representative of the first physiological characteristic of the reference person over time. The invention further relates to an apparatus and system for as biometric authentication/identification of a person.



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.

Method and apparatus for biometric authentication/identification of a person

The present invention relates to a method of biometric authentication/identification of a person. The invention further relates to an apparatus and a system for biometric authentication/identification of a person, as well as to a computer program product.

5 With the introduction of cheap biometric sensors, and low-cost computing platforms biometric authentication/identification of individuals is becoming more common in the world around us. Biometric authentication and identification are related concepts. During biometric authentication an alleged identity of a person being authenticated is validated using a feature vector derived from a physiological characteristic. This feature vector is established
10 based on a physiological characteristic of the person such as e.g. a feature vector derived from a fingerprint of a finger of the person being authenticated. During authentication the person also supplies an alleged identity, such as her name. The feature vector is subsequently matched with an enrolled feature vector that was obtained from the person associated with the alleged identity. Based on this comparison the person is either authenticated as having the
15 alleged identity or not.

 Similarly identification also involves establishing a feature vector for the person, in this case the person being identified. This feature vector is matched with enrolled feature vectors stored in a database. In case of identification this involves, at least one, but typically many, matches with enrolled feature vectors of different reference persons, until a
20 (sufficient) match is found, or the database is exhausted. As both authentication and identification involve a comparison of an acquired feature vector with an enrolled feature vector, authentication is often described as being a one-to-one comparison, whereas identification is a one-to-many comparison.

 People authenticate/identify themselves on a regular basis, for example when
25 presenting a passport at customs or using a badge to gain access to their office. Biometric authentication/identification has gained popularity due to the nature of biometrics. Biometric characteristics are closely coupled to a single person and generally cannot be transferred to another person. Moreover biometric characteristics are generally difficult to duplicate/forged.

Consequently biometric authentication/identification are generally considered to be more secure than e.g. the use of tokens for authentication/identification.

Biometric authentication/identification are also attracting the interest of counterfeiters, and other malicious parties that aim to thwart security systems. And while many people are under the impression that biometric systems are infallible, research has repeatedly shown that this is not the case, such as illustrated by e.g. "Impact of Artificial "Gummy" Fingers on Fingerprint Systems" by Tsutomu Matsumoto, et al. published in the Proceedings of SPIE Vol. #4677, Optical Security and Counterfeit Deterrence Techniques IV, 24-25 January 2002. This document illustrates the impact of imposter attacks using "gummy" fingers.

In response to the above development the industry has attempted to counter imposter attacks on biometric authentication/identification systems by e.g. combining multiple biometric techniques into multi-modal systems. Consequently it may no longer suffice to provide a gummy finger with the correct fingerprint, as the gummy finger may not pass other tests. In many of these multi-modal systems a primary identification/authentication system is used that provides the discerning characteristics needed to identify/authenticate a person, whereas a secondary system is used to validate the primary identification/authentication.

It is an object of the present invention to provide a method to at least in part counter imposter attacks on biometric authentication/identification systems.

This objective is realized by a method of biometric authentication/identification of a person according to claim 1.

The present invention provides a method of biometric authentication/identification that comprises the step of using a predictable time-variant first physiological characteristic. As indicated earlier, feature vectors may be derived from the first physiological characteristic that are representative of the first physiological characteristic of the person at a particular timestamp. E.g. a feature vector representative of the height of the junction between epidermis and dermis may be derived from a finger of a person being authenticated/identified at the time of authentication/identification.

By using a predictable time-variant physiological characteristic it is possible to establish a model of a feature vector representative of the first physiological characteristic of a reference person over time. Such a model can be a generic model valid for all individuals, or a model that is specific to a particular reference person and was established during

enrolment. This model can be used to establish an expected feature vector of the reference person at a particular timestamp, or alternatively can be used to establish a timestamp when the feature vector has a particular value.

The present invention proposes to use such a model to establish consistency of a first reference point comprising a first timestamp being the time of authentication/identification of the person and a first feature vector being a feature vector representative of the first physiological characteristic of the person at the first timestamp with the model of the reference person. It is important to note that the first reference point is associated with the person being authenticated/identified, whereas the model is associated with the reference person. After establishing consistency, the outcome thereof can be used in the decision making for the authentication/identification.

The present invention thus provides an enhanced method of authentication/identification in that the present invention can be used to reduce the number of false positives. The present invention can be used to rule out that the person authenticating/identifying himself/herself is the reference person when the first feature vector is not consistent. Alternatively, when consistency is established this corroborates that the person can be the reference person.

For example, the present invention may be used to counter imposter attacks using a gummy finger by determining the height of the junction between the epidermis and the dermis of a finger during authentication/identification and matching this with the model of the reference person. Not only will such a gummy finger generally not be consistent with the model at the time of authentication/identification, but moreover it will not show the same feature vector development over time as the actual finger. As a result this particular imposter attack can be thwarted using the present invention, thereby preventing a false positive authentication/identification decision.

In a preferred embodiment of the present invention establishing consistency of the first reference point with the model of the reference person comprises establishing a difference measure indicative of the extent to which the first reference point is inconsistent with the model of the reference person. Once the difference measure is established it is verified whether the difference measure is within a predetermined range. If the difference measure is within the predetermined range the first reference point is deemed consistent, if the difference measure is outside the predetermined range the first reference point is deemed inconsistent.

Provided the underlying first physiological characteristic exhibits the same or a sufficiently similar development over time for all individuals, a single model of the feature vector of the reference person over time can be used for all reference persons. However this model will require personalization, by means of temporal synchronization to the specific individual. In a preferable embodiment the model is adapted for each individual reference person, using a second reference point comprising a second timestamp corresponding to a time of enrolment of the reference person and a second feature vector representative of the first physiological characteristic of the reference person at the time of enrolment.

In this manner individual differences with respect to the development of the feature vectors over time can be accounted for. In order to minimize computational requirements the model may be adapted during enrolment and stored together with other enrolment data for the reference person. Alternatively, provided the storage of adapted models for each reference person requires too much storage capacity, the second reference point may be stored instead, allowing the generic model to be adapted on-the-fly during authentication/identification.

In a preferable class of embodiments according to claim 4, the difference measure corresponds to the distance between a first curve based on the model through the first reference point and a second curve based on the model passing through a second reference point associated with the reference person. The second curve corresponds with the actual model over time, whereas the first curve can be derived from the second curve by translating the second curve either along the time axis or along the feature vector axis/axes until the first curve passes through the first reference point.

In a more preferable class of embodiments according to claim 5, the difference measure is established by selecting a first point located on one of the first curve and the second curve, and predicting a second point by projecting the first point along the time axis or along the feature vector axis/axes onto the other one of the first curve and the second curve. Consequently the second point has either the timestamp or the feature vector value in common with the first point. Subsequently the difference measure can be computed by computing the distance between the first and the second point. The advantage of this manner of establishing a difference measure is its simplicity; it requires the projection of a single point onto a curve, and the computation of a single distance.

In a preferable embodiment according to claim 7, establishing the difference measure comprises a summation of the absolute value of the differences between the first and the second curve. In case the first physiological characteristic is cyclic claim 8 provides a

more preferable embodiment wherein the summation is a summation over one period of the first physiological characteristic, thereby simplifying the summation.

In a further embodiment the method of authentication/identification is a multi-modal authentication/identification method, wherein the first physiological characteristic is used as a modality for validating the outcome of the authentication/identification of a further modality. This embodiment enables the combination of a stable primary modality that has sufficient discerning capabilities for authentication/identification, with a time-variant, possibly less discerning, secondary modality.

In yet a further embodiment, multiple secondary time-variant modalities are used to verify time consistency. This embodiment is particularly advantageous when using time based difference measures, as it involves combining scalar time based difference measures.

In a further embodiment the method further comprises a step for storing the first reference point, the storing in part dependent on a positive authentication/identification decision. In this manner it is possible to acquire up to date enrolment data based on the first reference point of the person being authenticated/identified, provided the authentication/identification was (sufficiently) successful.

In a further embodiment, closely linked to the above embodiment, the method comprises a step for updating the model using the first reference point, provided that authentication/identification was positive. This embodiment allows the present invention to track changes over time that are a-typical for the development of the first physiological characteristic of a particular reference person. A good example of such an a-typical change is an increased drop in bone mineral density as a result of prolonged exposure to a particular medication.

It is a further object of the present invention to provide a device and a system to counter attacks on biometric authentication/identification systems.

These objectives are realized by an apparatus for biometric authentication/identification of a person according to claim 16, and a system for biometric authentication/identification of a person according to claim 18.

These and other aspects will be further elucidated and described with reference to the drawing in which:

Fig. 1, shows a graph of a generic model M_{ref} of a time-variant first physiological characteristic over time.

Fig. 2, shows a graph of two models, M_1 and M_2 for two individuals based on a generic model M_{ref} and enrolment data of a first person and a second person respectively.

5 Fig. 3, illustrates the determination of a difference measure using the first reference point as the first point for predicting a second point.

Fig. 4, illustrates the determination of a difference measure using the second reference point as the first point for predicting a second point.

10 Fig. 5, illustrates an alternate determination of a difference measure using a first point for predicting a second point.

Fig. 6, illustrates two issues related to the modeling of cyclic first physiological characteristics.

Fig. 7, illustrates the determination of a further difference measure for a non-cyclic first physiological characteristic.

15 Fig. 8, illustrates the determination of a further difference measure for a cyclic first physiological characteristic.

Fig. 9, depicts a block diagram of a device for biometric authentication of a person according to the present invention.

20 Fig. 10, depicts a block diagram of a system for biometric identification of a person.

Throughout the drawing, the same reference numeral refers to the same element, or an element that performs the same function.

25 In order to be able to apply the present invention it is important to select a suitable physiological characteristic and subsequently generate or parameterize a model of a feature vector representative of the first physiological characteristic over time. The human physiology offers a variety of time-variant physiological characteristics. Some of these characteristics exhibit a gradual change throughout the natural life of a person, such as the
30 bone mineral density. Other processes exhibit a much faster rate of change, such as cortisol levels in human blood.

Time-variant first physiological characteristics suitable for use by the present invention are not limited to e.g. monotonously increasing/decreasing time-variant characteristics. In fact embodiments are feasible that use transient or cyclic changing

physiological characteristics having either a slow or fast rate of change. For example any one of the following physiological characteristics may be used as the first physiological characteristic:

- the height of the junction between epidermis and dermis,
- 5 - the height of a person,
- the dimensions of the ear,
- the dimensions of the nose,
- the collagen density in the dermis,
- the bone mineral density, and
- 10 - the cortisol levels in human blood.

Not all types of physiological processes are equally well suited for use in authentication/identification. For example it would be highly inappropriate, if not illegal, to perform an invasive blood measurement in order to authenticate a person when crossing a
15 national border. However many physiological processes including transient and cyclic processes may be measured in a non-invasive manner.

Once a suitable time-variant physiological characteristic has been established, it is important to establish whether the characteristic is sufficiently predictable. The predictability is closely coupled to the intended application. In a scenario wherein a person
20 authenticates/identifies herself, typically at least one, or multiple times a day, it may suffice to be able to predict the physiological characteristic accurately within a range of one or two weeks, thereby providing an opportunity to “synchronize” the model of a feature vector representative of the first physiological characteristic over time to the actual first physiological characteristic.

25 On the other hand in situations where a person only occasionally authenticates/identifies herself, it may very well be necessary to be able to predict the physiological characteristic with a sufficient accuracy over a period of a year. Typically the latter constraints are satisfied easier when using slowly varying physiological characteristic(s) rather than using rapidly varying physiological characteristic(s). However, it
30 is not the rate of change that is decisive but the predictability thereof.

Once a suitable time-variant first physiological characteristic is selected a model may be generated of a feature vector representative of the first physiological characteristic over time. Techniques for creating a model of the first physiological characteristic are well known to those skilled in the art, and may involve curve-fitting

techniques, or piece-wise linear modeling techniques. The advantage of using a piecewise linear model is that it not only allows fast forward calculations, i.e. from timestamp to feature vector, but moreover also enables fast reverse operation, i.e. from feature vector to timestamp.

5 A simple, yet practical example of a suitable time-variant physiological characteristic is the bone mineral density. By establishing an average of the variation of the bone mineral density over a wide range of test-subjects, a model may be generated of a feature vector representative of the bone mineral density as a function of the age of a person. This type of model, having a time related input, is particularly useful when determining
10 predictions of a feature vector. Alternatively a model of the age as a function of a feature vector representative of the bone mineral density may be generated, the latter being particularly useful when determining predictions of timestamps. Either model may be used individually or together in a method according to the present invention.

 Fig. 1 shows a graph of a generic model M_{ref} of a feature vector representative
15 of a slowly changing time-variant first physiological characteristic over age. As can be seen from the graph the value Q of the time-variant first physiological characteristic decreases monotonously over time, until it is close to 0 at the age of 80. Although the model depicted here involves a feature vector comprising a single component Q the present invention is not limited to single component models.

20 Models that involve multiple components may be simplified by considering each individual component as a separate physiological characteristic that is modeled over time. Consequently a physiological characteristic with multiple components can be interpreted as multiple independent single component physiological characteristics that are combined in the decision for authentication/identification. Although a straightforward
25 simplification this way of working may not yield the best possible results.

 A model of a feature vector representative of a physiological characteristic comprising N -components over time can also be interpreted as a curve in an N -dimensional space that represents the N -components over time. In order to determine whether an acquired first feature vector corresponds with the model one could calculate the distance between a
30 feature vector acquired from a person being authenticated/identified, a first point in this N -dimensional space, and a corresponding second point on the curve. Using this approach it is possible to establish a distance measure that considers all components simultaneously, e.g. by calculating an N -norm for verifying whether the first point is within a predetermined distance

from the second point, that corresponds to a point on the curve described by the model. This added accuracy/reliability comes at the cost of added complexity.

In order to be able to authenticate/identify a person using biometrics, persons need to be enrolled. During enrolment the first physiological characteristic is measured resulting in a second feature vector as well as a second timestamp corresponding with the time of enrolment. The second feature vector and the time of enrolment form a second reference point. The second reference point for each reference person is stored together with a unique identifier for later reference. This unique identifier could be the identity of the reference person or a reference for establishing that identity, such as a reference-number or a (hyper)link.

In some systems for biometric authentication/identification enrolment data is generated in a similar manner as feature vectors during authentication/identification. More often the enrolment procedure involves multiple measurements and additional processing in order to obtain a better quality enrolment data.

Once enrolment data of (a) reference person(s) is available it is possible to adapt a generic model of the first physiological characteristic to create a model for each individual reference person, provided the model of the first physiological characteristic so requires. Fig. 1 shows a general model representative of the first physiological characteristic M_{ref} . Assume that the shape of the monotonous decrease shown is representative for humans in general. Further assume that the height of the curve is different for different individuals. During enrolment the general model will have to be scaled to compensate for differences between individuals.

Fig. 2 illustrates how the model of a first physiological characteristic M_{ref} may be adapted for two individuals. On January 1st, 2000, a first person is enrolled, age 36. The value of the second feature vector acquired during the enrolment is represented by Q_1 . Next the model M_1 for this first person is established using this measurement and the general model representative of the first physiological characteristic M_{ref} . The general shape of the curve M_1 is identical to that of the curve M_{ref} but it is scaled such that the second reference point for the first person (36 (age), Q_1) is on the curve, yielding the curve M_1 representative of the first person. During the enrolment of a second person in 2000, age 17, a value Q_2 was measured for the second feature vector. Subsequently the curve M_{ref} is first translated to match the age of the person in 2000, and the curve is subsequently scaled such that the point (17 (age), Q_2) is on the curve M_2 .

Although Fig. 2 shows an example that involves scaling along the axis of the feature vector, other first physiological characteristics may require scaling along the time-scale axis or other operations. The above is merely an example of how a general model may be modified according to enrolment data. In case the model requires adaptation for each enrolled person, such model parameters or the model itself will have to be included with the enrolment data. In case no such customization is required a single model can be used that need not be part of the enrolment data.

It will be clear to the skilled person that the more adaptations are required the more reference points are needed to tune the model. This is particularly true for models that model cyclic behavior where not only the amplitude of the model but also the frequency has to be established and where there is a risk of sub-sampling. The use of physiological models that model multiple components over time may also require different adaptations for the various components.

Once a model of a feature vector representative of a suitable first physiological characteristic of a person has been established, it is possible to utilize the first physiological characteristic as well as the model of that characteristic in a method of biometric authentication/identification according to the present invention. Using the above way of working a model can be established, e.g. during enrolment of each reference person. Upon an authentication/identification attempt of a person, a first reference point comprising a first timestamp and a first feature vector of the person being authenticated/identified is used to establish consistency of that first reference point with at least one model of a reference person.

The first reference point is a point in a multi-dimensional space with as dimensions, time and the feature vector dimensions. The model in turn, represents a curve in the same space. In order to establish consistency it is possible to establish whether the reference point of the person is sufficiently close to the curve of the reference person. As the first reference point is based on potentially noisy acquisition data it is important to account for such noise in the comparison. In one embodiment noise is accounted for by defining that the point is consistent if it is sufficiently close, that is within a pre-determined range from the curve.

A preferred manner to establish consistency is to establish a point on the curve corresponding to the first reference point, for example by selecting a point on the curve with the same time-stamp, or with the same feature vector value. Subsequently the distance between the reference point and the selected point can be calculated, and used as a difference

measure. The advantage of this particular manner of determining a difference measure is that it does not involve complex computations. Next several manners for determining a difference measure will be presented in more detail.

During authentication/identification a first reference point (T_{acq}, Q_{acq}) is acquired as depicted in Fig. 3. The first reference point comprises a first timestamp T_{acq} corresponding to the time of authentication/identification of a person and a first feature vector Q_{acq} representative of the first physiological characteristic of the person at the first timestamp T_{acq} . In addition a second reference point is acquired (T_{erl}, Q_{erl}) as depicted in Fig. 3. The second reference point comprises a second timestamp T_{erl} corresponding to the time of enrolment of a reference person and a second feature vector Q_{acq} representative of the first physiological characteristic of the reference person at the second timestamp T_{erl} .

Using the model a first curve M_a may be defined based on the model of the first physiological characteristic that passes through the first reference point. In addition a second curve M_e can be defined that passes through the second reference point, both curves identical in shape, the first curve having an offset with respect to one of the timestamp values and the feature vector values compared to the second curve. Although this may appear straightforward keep in mind that the first reference point is associated with the person being authenticated/identified whereas the model is associated with the reference person. Subsequently a difference measure is determined representative of the distance between the first curve M_a and the second curve M_e .

A first manner to establish a difference measure, in accordance with claim 6, is presented in Fig. 3. The first reference point (T_{acq}, Q_{acq}) is used as a first point for predicting a second point located on the second curve M_e . To this end the value is determined of the second curve M_e at the first timestamp T_{acq} , corresponding to the feature vector of the second point S_1 . The difference measure for this particular case is indicated by difference measure d_1 , representing the difference in the respective feature vector of the first reference point (T_{acq}, Q_{acq}) and the second point S_1 .

A second manner to establish a difference measure in accordance with claim 6, is also presented in Fig. 3. This second approach also starts with the selection of the first reference point, as the first point for predicting a second point. Subsequently a second point S_2 is established, by determining the timestamp when the curve M_e equals the first feature vector value Q_{acq} . The difference measure for this particular case is indicated by difference measure d_2 , representing the difference in the respective timestamps of the first reference point (T_{acq}, Q_{acq}) and the second point S_2 .

Once the difference measures have been established they can be used in a method according to the present invention. It will be clear to the skilled person that the first manner and the second manner of establishing a difference measure will benefit from using respectively a model of the first feature vector as a function of time and a model of the timestamp as a function of the feature vector.

Although the examples for determining a difference measure as presented in Fig. 3 both use the first reference point (T_{acq}, Q_{acq}), as the first point it is also possible to use the second reference point (T_{erl}, Q_{erl}) as the first point, and use this to predict a second point on the first curve M_a as depicted in Fig. 4. Fig. 4 also depicts a further difference measure d_3 representative of the distance between the first curve M_a and the second curve M_e . Although the first and the second curve are plotted in order to visualize the difference measure calculation, it is not necessary to plot or calculate all points on the curves in order to establish the difference measure.

Fig. 5 illustrates an embodiment according to claim 5. After acquiring a first reference point (T_{acq}, Q_{acq}) and a second reference point (T_{erl}, Q_{erl}), a difference measure representative of the distance between a first curve M_a through the first reference point and a second curve M_e through the second reference point can be determined.

In order to determine this difference measure, a first point P_1 is selected. The first point P_1 is located on one of the first or the second curve, in the example in Fig. 5 on the second curve M_e . After selecting the first point P_1 a second point is predicted using the model M of the first physiological characteristic. The second point being a point on the other of the first and second curve, in the example in Fig. 5 the first curve M_a .

A first manner to compute a distance measure d_1 , involves determining the value of the feature vector of the first curve M_a at the timestamp corresponding to the first point P_1 , in this case this corresponds to the feature vector of the second point S_1 . The difference measure for this particular case is indicated by difference measure d_1 , representing the difference in the respective biometric values of the first point P_1 and the second point S_1 .

A second manner to compute a distance measure d_2 can be determined by determining the value of the timestamp when the first curve M_a has a feature vector corresponding to that of the first point P_1 , in this case this results in the second point S_2 . The difference measure for this particular case is indicated by difference measure d_2 , representing the difference in the respective timestamps of the first point P_1 and the second point S_2 .

Throughout Fig. 3-5 establishing the difference measure comprises using the model to establish an alternate reference point comprising a feature vector and a timestamp representative of either the person or the reference person.

Once a difference measure is established, it may be used for verifying whether the difference measure is within a predetermined range, typically this predetermined range will correspond with the absolute value of the difference measure being below a predetermined threshold. If this is not the case, then this may be seen as a proof that the person being authenticated/identified (associated with the first reference point) is not the same person as the reference person (associated with the second reference point). On the other hand when the difference measure is within range the person being authenticated/identified can, but need not, be the reference person.

Verifying the consistency of the first reference point with the model provides a so-called false-proof. It corroborates or rules out an authentication/identification rather than that it provides an authentication/identification of a person.

Fig. 6 illustrates two issues associated with modeling a cyclic time-variant first physiological characteristic. When modeling a cyclic first physiological characteristic typically multiple enrolment data are required. Fig. 6 illustrates such by means of the points E_1 , E_2 , E_3 , and E_4 . Following the enrolment measurements, the generic model may be adapted, such that the enrolment data are on the generic model, here the curve M_e . In case of a cyclic first physiological characteristic it is important to prevent sub-sampling. The curve M_{ss} is presented to illustrate a further shape-wise similar curve that passes through the same enrolment points as M_e , but has approximately a six times higher frequency than that of M_e . This example illustrates that the generation of a model requires knowledge of the first physiological characteristic, in order to prevent sub-sampling (Nyquist sampling theorem).

Fig. 6 further highlights a problem that occurs when using a cyclic model to predict a second point. Due to the cyclic nature of the model there typically will be multiple timestamps when the model evaluates to a particular feature vector. A similar problem may occur with an a-cyclic model wherein multiple timestamps have the same feature vector value. When predicting a second point on the curve M_e with the same biometric value as the first point, here the first reference point (T_{acq}, Q_{acq}) , multiple points will be found with a feature vector value identical to that of the first feature vector Q_{acq} .

In these cases the first timestamp T_{acq} may be used to select the timestamp predictions that are closest to the acquired first or second timestamp respectively. Fig. 6

illustrates the selection of relevant candidate timestamps using T_{acq} resulting in the timestamps T_{pacq2} , and T_{pacq3} , the timestamps closest to the first timestamp T_{acq} .

Fig. 7 illustrates a difference measure determination in accordance with claim 7. First a first reference point (T_{acq}, Q_{acq}) and a second reference point (T_{erl}, Q_{erl}) are acquired. Using the model M of the first physiological characteristic the first curve, and the second curve can be established M_a and M_e respectively. Once the curves are established the difference measure representative of the distance between the first and the second curve can be established.

In accordance with claim 7, establishing the difference measure d_{A1} comprises the summation of the absolute differences between the first and the second curve for an a-cyclic first physiological characteristic. In order to establish the difference measure d_{A1} the area $A1$ is established by summation of the absolute differences between the first and the second curve over the overlapping period, here 1964-2014. The difference measure d_{A1} is derived from $A1$ by dividing $A1$ by the overlap in time, here 40 years.

Fig. 8 illustrates a difference measure determination in accordance with claim 8 for a cyclic first physiological characteristic. Similar to the situation in Fig. 7 the first curve M_a and the second curve M_e are established. Once established the area $A2$ is established by means of the summation of the absolute differences between the first and the second curve over one period of the cycle. In Fig. 8 the area $A2$ corresponds to the hatched areas. Although the area $A2$ can be used as a difference measure, it is possible to factor out the period and use $A2/T_p$ as a difference measure instead.

Fig. 9 shows an apparatus 805 for biometric authentication of a person according to the present invention. The apparatus 805 represents an apparatus that is arranged to use two modalities for authentication: a fingerprint and a time-variant first physiological characteristic. The first modality, the fingerprint 801, is used to authenticate the individual, and will not be discussed here. The second modality 802, the time-variant first physiological characteristic, is used to establish consistency of a feature vector acquired during authentication from the person being authenticated with a model of a reference person comprised in the enrollment data of that reference person.

The apparatus 805 comprises an acquisition means 810, an establishing means 820, a verification means 830, and a decision means 840. The apparatus 805 further comprises an on-board timer 850, and storage means 860.

The storage means 860 comprises a biometric database. The biometric database comprises entries that correspond to enrolment data of previously enrolled persons.

An enrolment data entry for a reference person here comprises: an identity and a model of a feature vector representative of the first physiological characteristic of the reference person over time. Although the enrolment data also comprises fingerprint enrolment data this is not considered here for clarity sake.

5 Although the apparatus 805 is arranged to authenticate a person, it may also be used to enroll a person, as the general process of feature vector acquisition is similar, but may involve repeated acquisition of feature vector and further processing thereof.

 When a person attempts to authenticate herself, she presents the appropriate finger 890 to the apparatus 805. The acquisition means 810 subsequently acquires her
10 fingerprint 801, and in addition acquires information 806 related to the first time-variant physiological characteristic. This information 806 is used by the acquisition means to establish a first feature vector 802. At the same time the acquisition means 810 acquires a first timestamp 803 from the on-board timer 850, corresponding to the time of acquisition. Although the depicted embodiment features an on-board timer the present invention is not
15 limited thereto, as an external timer can be used instead.

 In addition the person also provides an ID-card 880 to the apparatus 805. The ID-card 880 comprises an alleged identity 809 of the person. The alleged identity 809 is used to retrieve an enrolment data 811 associated with the alleged identity 809 from the biometric data 860. The enrolment data 811 comprises the alleged identity 809 and a model of a feature
20 vector representative of the first physiological characteristic of the person having the alleged identity 809 over time.

 The first establishing means 825 is arranged to establish consistency of the first reference point with the model of the reference person. Here the first establishing means 825 comprises a second establishing means 820 arranged to establish a difference measure
25 812 indicative of the extent to which the first reference point is inconsistent with the model of the reference person, and a verifying means 830 arranged to verify whether the difference measure 812 is within a predetermined range. For more information with respect to various ways for the determination of difference values see the figure descriptions of Fig. 3-8.

 The verification means 830 receives the difference measure 812 and verifies
30 whether the difference measure 812 is within a predetermined range. The outcome 814 of this verification is presented to the decision means 840.

 The decision means 840 combines the outcome 814 of the verification with an outcome 816 of the fingerprint authentication into an authentication decision 817. In this particular embodiment the authentication outcome 816 is accepted when the first feature

vector 802 at the first timestamp 803 is sufficiently consistent with the enrolment data of the reference person, otherwise the authentication outcome 816 is rejected. This result is presented on the output of the decision means in the form of the authentication decision 817.

It will be clear to those skilled in the art that the verification means 830 and decision means 840 may be combined such that the verification means 830 does not provide an outcome 814 in the form of a hard decision, consistent or inconsistent, but provides a probability instead. Provided the fingerprint authentication method also provides a probability, a more accurate soft decision can be made.

The present invention can be applied in an advantageous manner for authentication purposes or for identification purposes alike. This can be illustrated using the apparatus 805. Although the apparatus 805 is an apparatus for authentication of a person, a slightly modified version of the apparatus may be used for identification. When identifying a person, the first feature vector 802 is matched repeatedly with feature vector from various candidate reference persons from the biometric data. This process may continue until a match is found or there are no more candidate reference persons left in the database.

In case of identification there is no need for a device for acquiring an alleged identity. Instead of comparing the first timestamp and first feature vector with the model associated with the alleged identity an apparatus for identification of a person compares the first timestamp and the first feature vector with enrolment data of at least one, but potentially many candidate reference persons until a sufficient match is found, or the database is exhausted.

Fig. 10 shows a system 900 for authentication/identification of a person the system comprises two devices 915 according to claim 16 suitable for identification. These respective devices are part of a system comprising a central biometric database 905, wherein the devices 915 acquire enrolment data from the central biometric database 905 over a network 910 rather than from an internal biometric database 860 as shown in Fig. 9.

The dashed arrows 925, and 930 are representative of the flow of enrolment data from the biometric data to the devices. Each device 915 may comprise a computer program product reader, arranged to read a computer program product comprising program code means stored on a computer readable medium 920, such as an optical disc, or a solid state memory device.

Throughout the application the first physiological characteristic is considered to be a predictable time-variant physiological characteristic. However variations/deviations may occur in the actual first physiological characteristic as a result of external influences. By analyzing the deviations that occur in respective first feature vector acquired during positive

authentication attempts, it is possible to establish changes, and trends. This information may be used to update the parameters of the model to compensate for such trends and provide a better match between the model and the actual first physiological characteristic of the individual. Such updates are particularly useful in case the first physiological characteristic is cyclic, as these updates allow "synchronization" of the model with the actual first physiological characteristic.

Although tracking, and synchronization of the adapted model are highly desirable, tracking changes in the first physiological characteristic by means of the acquired feature vectors embodies an inherent risk. By tracking changes in the feature vectors rather than the actual physiological characteristic noise and structural errors in the feature vector generation may lead to erroneous updates that may make the system less robust. This however may be circumvented by means of a periodic re-enrolment.

Even though the graphs presented in this application, are graphs of feature vectors that comprise only a single component, the present invention is not limited thereto. In fact the present invention may be applied in an equally advantageous manner for feature vectors that comprises multiple time-variant components. It will be clear to those skilled in the art that similar techniques may be applied to multiple time-variant components as are applied to a single time-variant component.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims.

In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. The word "comprising" does not exclude the presence of elements or steps other than those listed in a claim. The word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements.

The invention can be implemented by means of hardware comprising several distinct elements, and by means of a suitably programmed computer. In the device claim enumerating several means, several of these means can be embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

CLAIMS:

1. Method of biometric authentication/identification of a person that comprises the step of using a predictable time-variant first physiological characteristic for establishing consistency of a first reference point comprising a first timestamp (T_{acq}) and a first feature vector (Q_{acq}) of the person being authenticated/identified with a model (M_1) of a reference person and authenticating/identifying the person as the reference person in dependence of the establishing, the first timestamp (T_{acq}) being the time of authentication/identification of the person, the first feature vector (Q_{acq}) being a feature vector representative of the first physiological characteristic of the person at the first timestamp, the model (M_1) being a model of a feature vector representative of the first physiological characteristic of the reference person over time.
2. Method of claim 1, wherein establishing consistency of the first reference point with the model of the reference person comprises:
 - establishing a difference measure (d_1, d_2, d_{A1}) indicative of the extent to which the first reference point is inconsistent with the model (M_1, M_2) of the reference person,
 - verifying whether the difference measure (d_1, d_2, d_{A1}) is within a predetermined range.
3. Method of claim 2, wherein the model incorporates a second reference point comprising a second timestamp (T_{enl}) corresponding to a time of enrolment of the reference person and a second feature vector (Q_{enl}) representative of the first physiological characteristic of the reference person at the time of enrolment.
4. Method of claim 3, wherein the difference measure (d_1, d_2, d_{A1}) corresponds to the distance between a first curve (M_a) based on the model through the first reference point and a second curve (M_e) based on the model through the second reference point, the first curve (M_a):
 - identical in shape to the second curve (M_e),
 - having an offset with respect to one of the timestamp values and the feature

vector values compared to the second curve, and

- passing through the first reference point.

5. Method of claim 4, wherein establishing the difference measure (d_1 , d_2)

5 comprises:

- selecting a first point (P_1) located on one of the first curve (M_a) and the second curve (M_e),
- predicting a second point (S_1 , S_2) by projecting the first point (P_1) onto the other one of the first curve and the second curve, wherein the second point (S_1 , S_2) has one of
- 10 the timestamp and the feature vector value in common with the first point (P_1).
- computing the difference measure (d_1 , d_2) by computing the distance between the first point (P_1) and the second point (S_1 , S_2).

6. Method of claim 5, wherein the first point (P_1) is the reference point located on

15 the one of the first curve (M_a) and the second curve (M_e).

7. Method of claim 4, wherein establishing the difference measure (d_{A1}) comprises a summation of the absolute value of the differences between the first and the second curve.

20

8. Method of claim 7, wherein the first physiological characteristic is cyclic, and the summation is a summation over one period (T_p) of a cycle.

9. Method of claim 1, wherein the method is a multi-modal

25 authentication/identification method, wherein the first physiological characteristic is used as a modality for validating the outcome of the authentication/identification of a further modality.

10. Method of claim 1, further comprising a step for verifying consistency of a

30 second physiological characteristic.

11. The method of claim 1, further comprising a step for storing the first reference point in part dependent on the outcome of the authentication/identification being positive.

12. The method of claim 1, further comprising a step for updating the model using the first reference point in part dependent on the outcome of the authentication/identification being positive.

5 13. Method of claim 2, wherein the difference measure (d_1 , d_2) is indicative of the distance between the first reference point and a corresponding point on the model.

14. Method of claim 2, wherein the difference measure (d_1 , d_2 , d_{A1}) quantifies one of a difference in feature vector value and a difference in timestamp.

10

15. Method of claim 2, wherein establishing the difference measure (d_1 , d_2) comprises using the model to establish an alternate reference point comprising a feature vector and a timestamp representative of one of the person and the reference person.

15 16. Apparatus (805) for biometric authentication/identification of a person wherein the apparatus (805) is arranged to utilize a predictable time-variant first physiological characteristic in order to establish consistency of a first reference point comprising a first timestamp (803) and a first feature vector (802) of the person being authenticated/identified with a model of a reference person, the first timestamp (803) being
20 the time of authentication/identification of the person, the first feature vector (802) being a feature vector representative of the first physiological characteristic of the person at the first timestamp, the model being a model of a feature vector representative of the first physiological characteristic of the reference person over time, the apparatus comprising:
- a first acquisition means (810) arranged to acquire the first feature vector (802)
25 representative of the first physiological characteristic of the person at the first timestamp (803),
- a first establishing means (825) arranged to establish consistency of the first reference point with the model of the reference person, and
- a decision means (840) arranged to authenticate/identify the person as the
30 reference person in dependence of the first establishing means (825).

17. Apparatus of claim 16, wherein the first establishing means (825) comprises:
- a second establishing means (820) arranged to establish a difference measure (d_1 , d_2 , d_{A1}) indicative of the extent to which the first reference point is inconsistent with the

model (M_1 , M_2) of the reference person, and

- a verifying means (830) arranged to verify whether the difference measure(d_1 , d_2 , d_{A1}) is within a predetermined range.

- 5 18. System for authentication/identification of a person the system characterized in that it comprises an apparatus according to claim 16.
19. Computer program product comprising program code means stored on a computer readable medium generated according to the method of any of the claims 1 to 15
- 10 when said program product is run on a computer.

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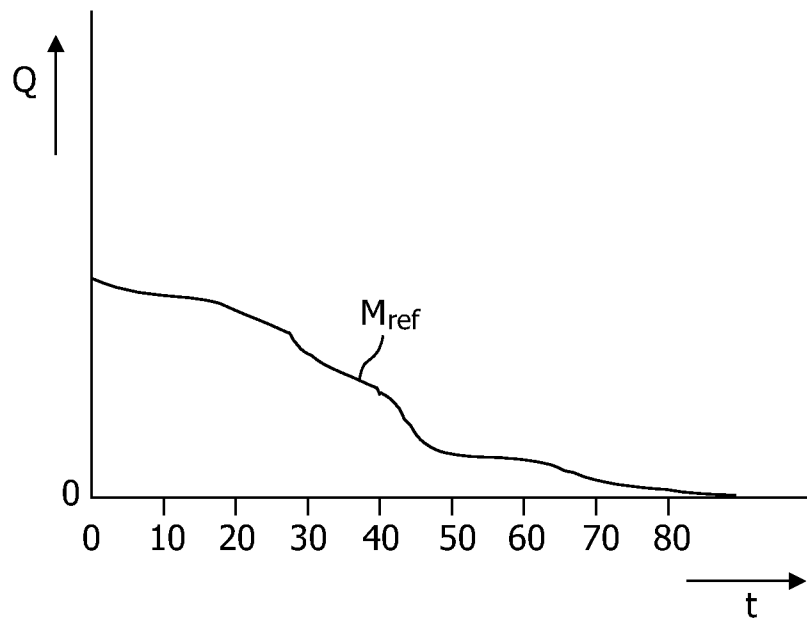


FIG. 1

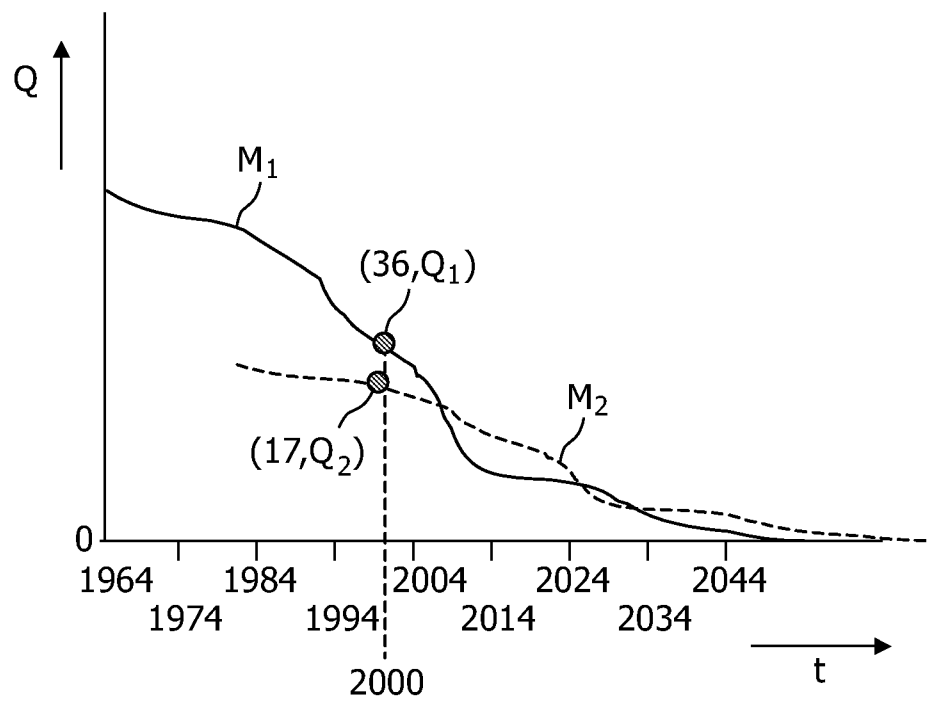


FIG. 2

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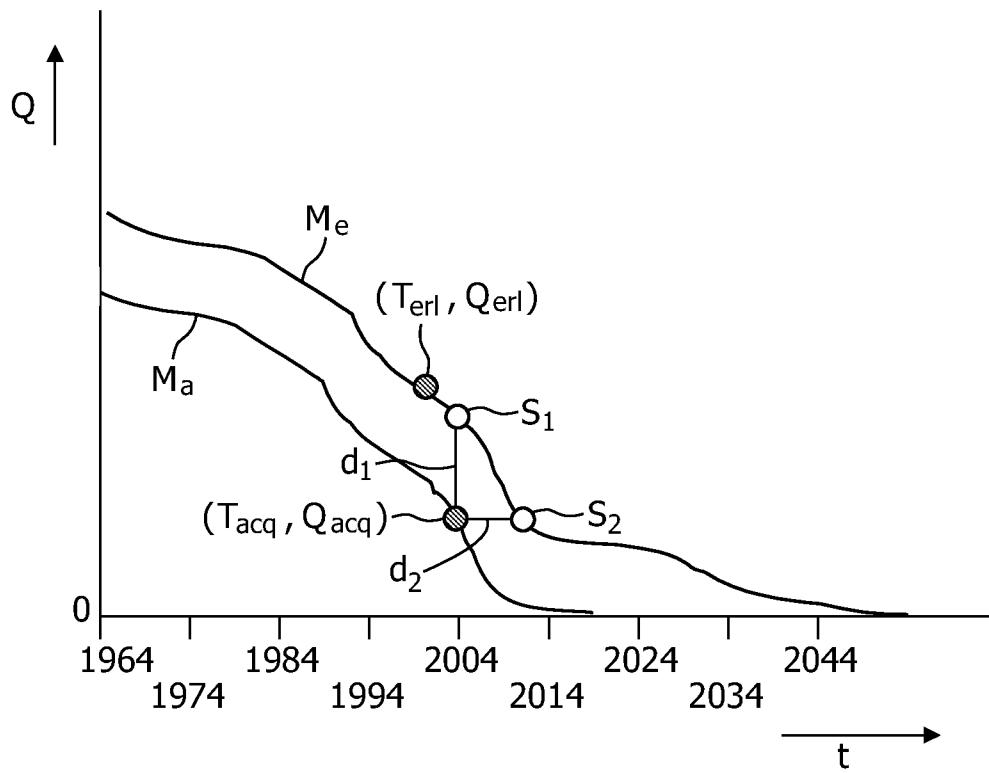


FIG. 3

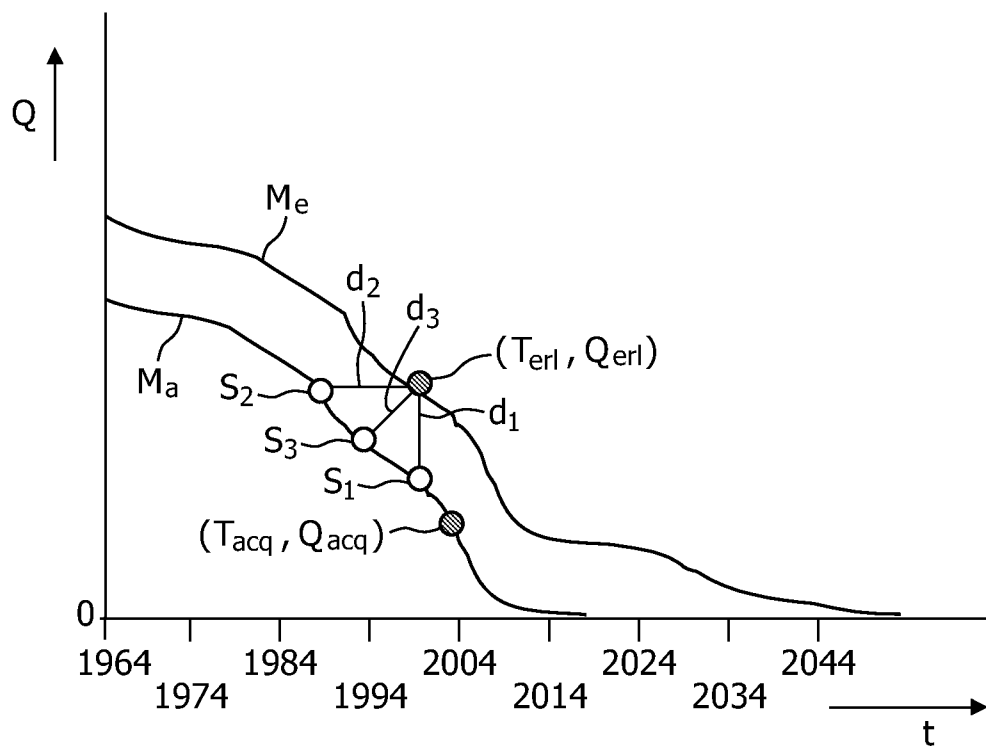


FIG. 4

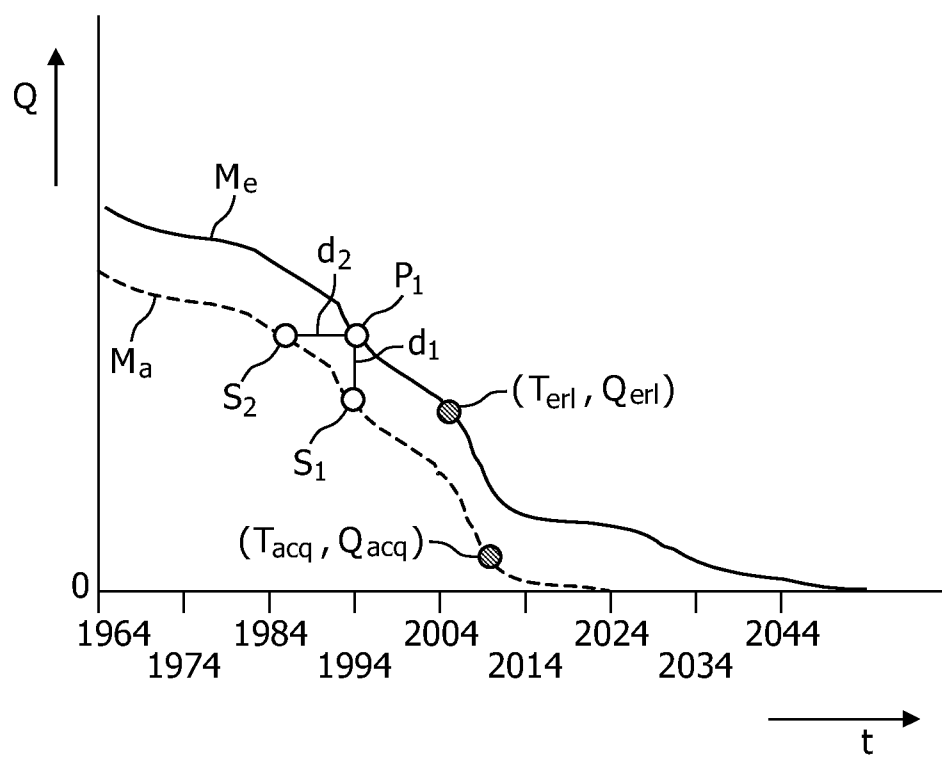


FIG. 5

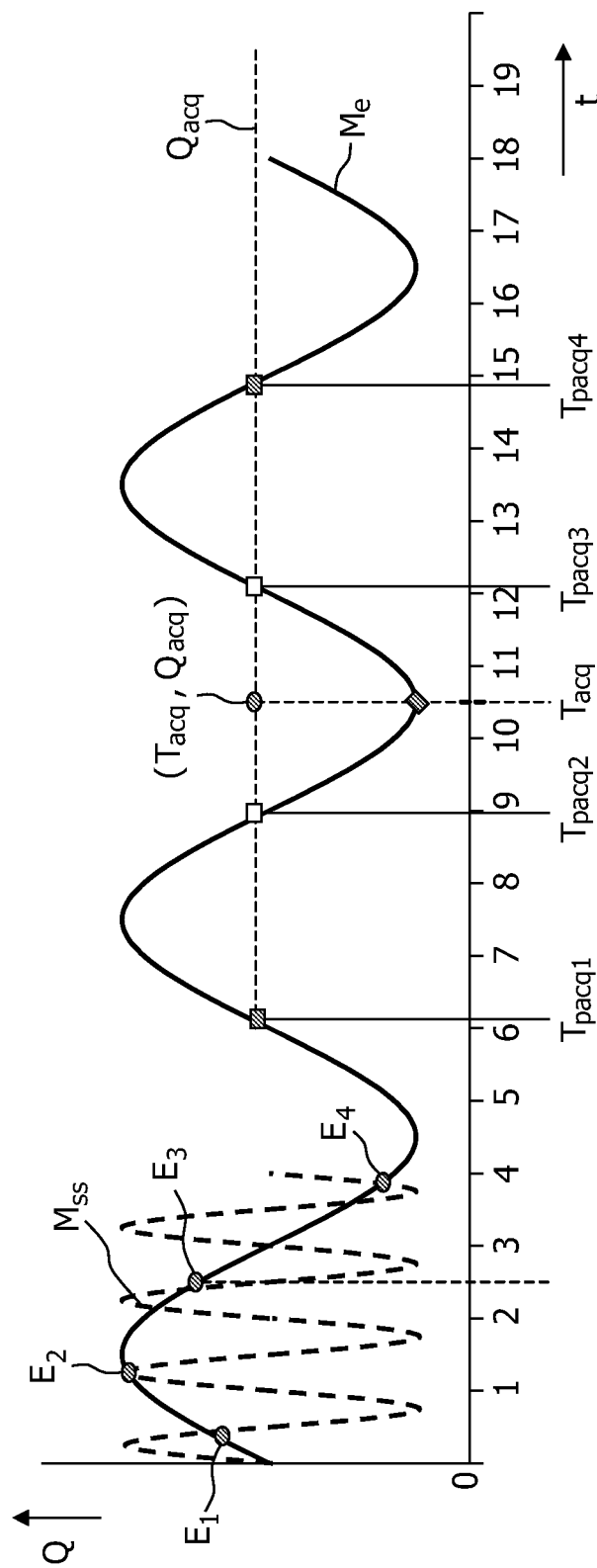


FIG. 6

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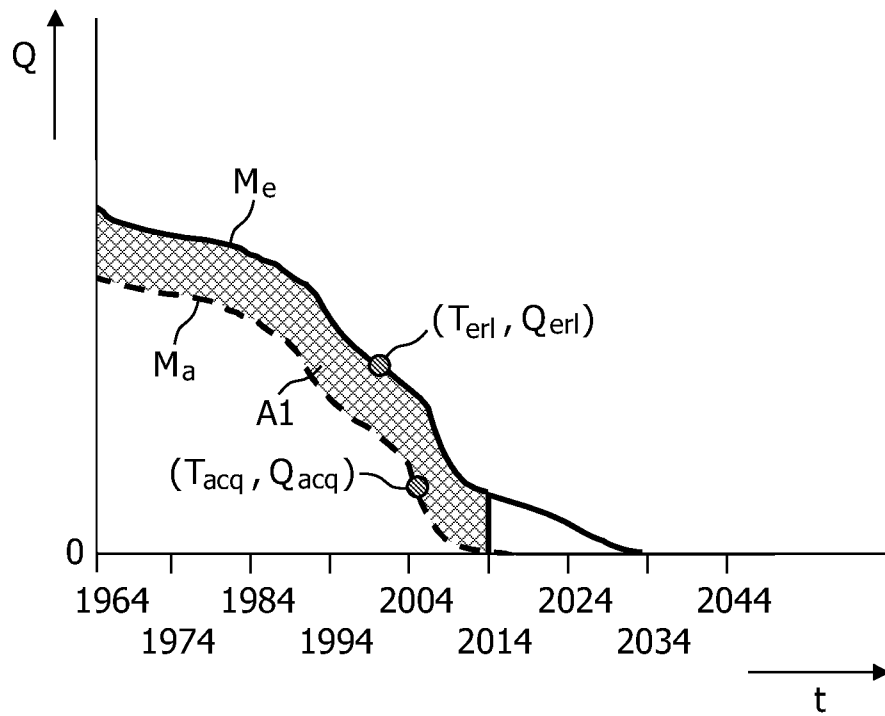


FIG. 7

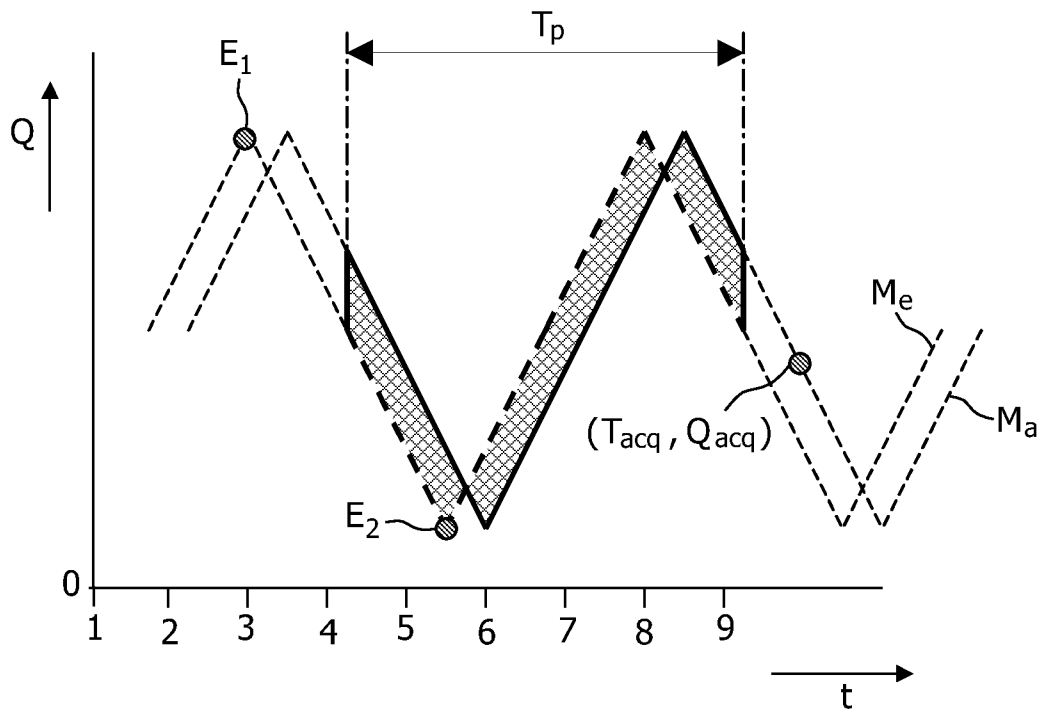


FIG. 8

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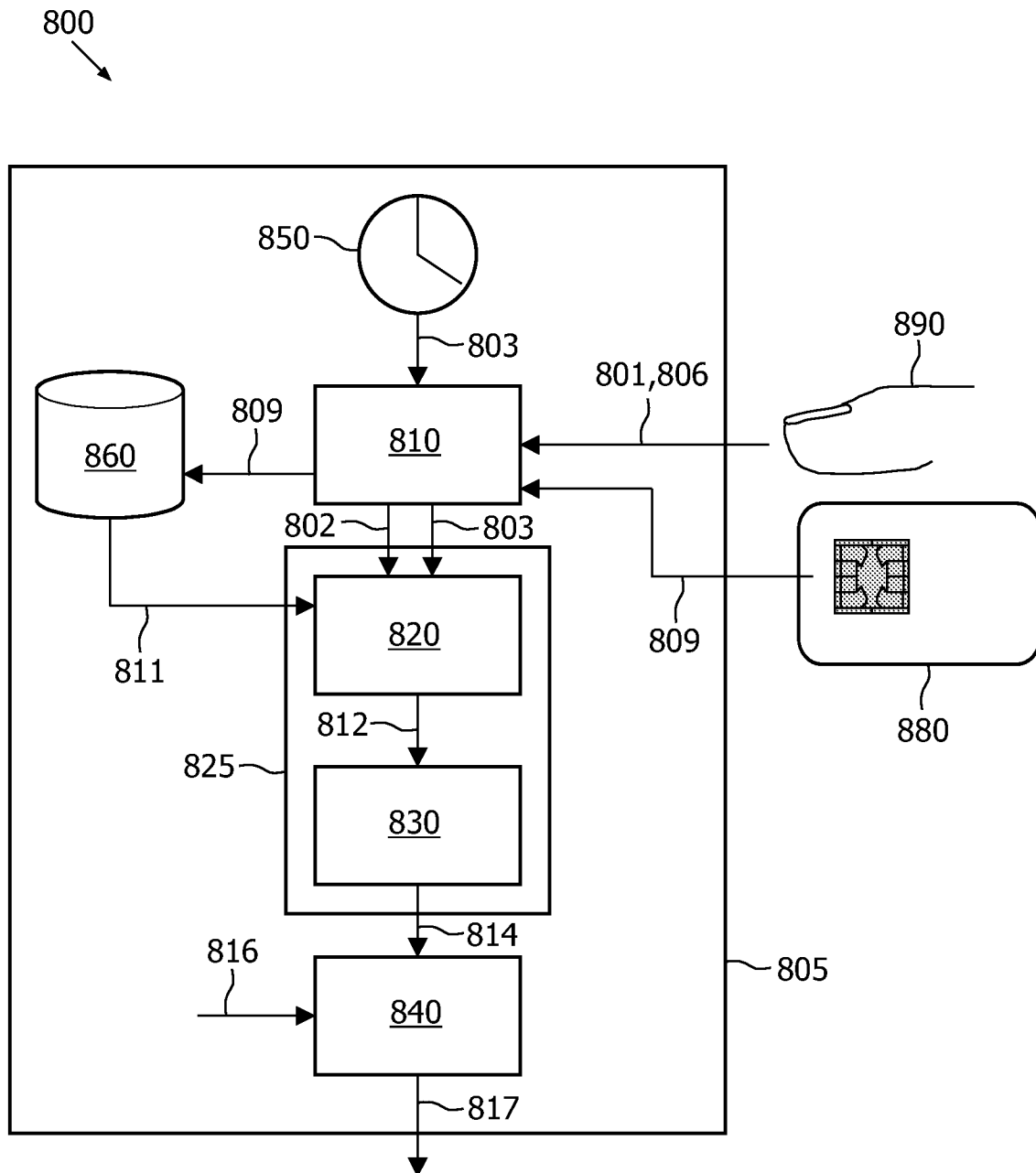


FIG. 9

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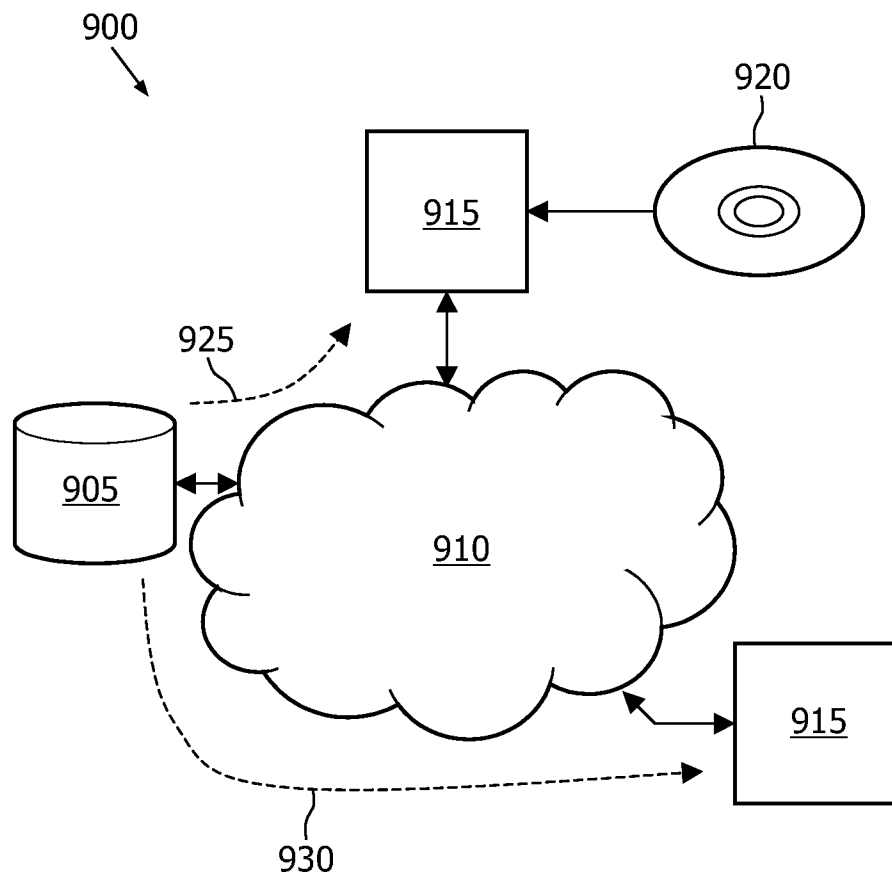


FIG. 10