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(54) **Title:** IMPROVED FINGERPRINT MATCHING IN IN-DISPLAY SOLUTIONS

(57) **Abstract:** Disclosed is a method for enrolling a fingerprint associated with a user and detected on a display in order to enroll the user.The display comprises ultrasonic sensors configured to detect fingerprints on the surface of the display. One or more positions on the display are defined, each position associated with a respective set of coordinates.The respective set of coordinates defines where on the display the one or more positions are located. The method comprises prompting the user to touch a first position on the display associated with a first set of coordinates one or more times, detecting at least one touch occasion in the first position of the display,resulting in a respective fingerprint,extracting a number of feature points from each respective fingerprint,forming one or more sub-templates comprising the extracted feature points, associating the sub-templates with the first position and storing the sub-templates.The number of feature points associated with the one or more stored sub-templates is associated with the enrolled user. Also disclosed is a method for verifying an enrolled fingerprint and an arrangement.

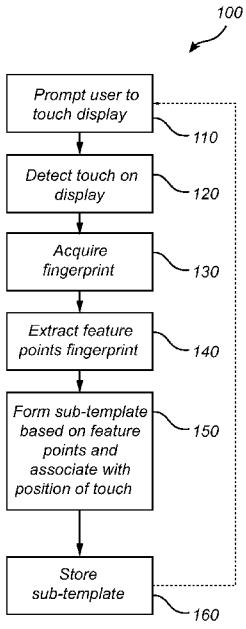


Fig. 1

WO 2019/135700 A1

# IMPROVED FINGERPRINT MATCHING IN IN-DISPLAY SOLUTIONS

## Technical Field

The present invention relates generally to the field of biometric based authentication. More particularly, it relates to improved fingerprint matching for in-display solutions.

## Background

To use biometrics as a form of identification in order to improve correct identification as well as security has been known for long. Use of biometrics such as fingerprints, retina scans, palm prints, and dental records are typically common.

When using e.g. fingerprints a user will typically have to at some point leave his or her fingerprint on a surface where it can be detected, when this has been done, one could typically say that the user has enrolled its fingerprint. When verifying the user a new image of the fingerprint is obtained and this is matched against the fingerprint that was previously enrolled.

Today, it is typically common that fingerprint acquisition is made on some form of digital display or on some sort of surface. Such surface may e.g. be a plate such as a glass or metal plate, possibly arranged on top of a digital display, wherein fingerprints are acquired, stored and compared for enrollment and verification (or authorization) by means of electronic circuitry.

One technology being used for acquiring fingerprints from e.g. a display is that of ultrasonic sensors (US). An advantage of the US-technology is typically that sensors may be arranged on or in association with a display such that an entire fingerprint may be acquired on multiple places on the screen.

However, due to the physical behavior of ultrasonic scattering and in some cases system limitations in terms of the number of possible transducer elements and their position on the display some impact may typically be made on the acquired fingerprints depending on where on the display they were acquired.

This is something that possibly could be compensated for in the fingerprint enrollment process, however it would typically lead to a cumbersome and time consuming process whose complexity would increase drastically when the number of enrolled fingerprints increases.

Therefore, there is a need for alternative methods and arrangements for verification and/or enrollment. Preferably, such methods and arrangements enable fast and/or simple enrollment and/or verification. Also preferably, this is achieved while still taking into consideration the different characteristics of the display.

**Summary**

It should be emphasized that the term "comprises/comprising" when used in this specification is taken to specify the presence of stated features, integers, steps, or components, but does not preclude the presence or addition of one or more other features, integers, steps, components, or groups thereof.

It is an object of some embodiments to mitigate at least some of the above disadvantages and to provide methods and arrangements for efficient and robust enrollment and verification of biometrics such as fingerprints for in-display acquisition.

According to a first aspect this is achieved by a method for enrolling a fingerprint associated with a user and detected on a display in order to enroll the user. The display comprises ultrasonic sensors configured to detect fingerprints on the surface of the display.

In some embodiments, the display may be a plate made of e.g. glass or metal arranged on-top of a digital display. In some embodiments, the display may be plate operatively connected to an electronic device.

Hence, in this disclosure the term "display" may be interpreted as a surface configured to acquire biometrics, such as a glass plate or a metal plate or a plastic plate etc.

Fingerprints may e.g. be detected everywhere on the display, or only on a part of the display.

One or more positions on the display are defined, each position associated with a respective set of coordinates, wherein the respective set of coordinates defines where on the display the one or more positions are located.

It should be noted that in this disclosure the term "position" may be used interchangeably with the term "location" unless explicitly stated otherwise.

The coordinates may be e.g. be Cartesian or polar coordinates.

The method comprises prompting the user to touch a first position on the display associated with a first set of coordinates one or more times.

The method may in some embodiments comprise prompting the user to touch the display at a certain position.

In some embodiments, the method may comprise prompting the user to just touch the display, without specifying where.

The method also comprises detecting at least one touch occasion in the first position of the display wherein each touch occasion results in a respective fingerprint and extracting a number of feature points from each of the respective fingerprint.

The respective fingerprint may e.g. in some embodiments be a partial fingerprint or a full fingerprint.

The method furthermore comprises forming one or more sub-templates comprising the number of feature points extracted from the respective fingerprint and associating the one or more sub-templates with the first position by storing information pertaining to the first set of coordinates in the sub-template and storing the one or more sub-templates associated with the first position.

A sub-template may e.g. be defined as a template which comprises feature points corresponding to a part of a fingerprint. In some embodiments, it may additionally or alternatively also be defined as a template comprising feature points associated with a fingerprint, wherein the template is associated with a certain position of the display and wherein the position may be associated with several templates comprising different feature points.

The sub-templates may e.g. be stored in a memory associated with the display. E.g. the display may be comprised within an electronic device which may have internal memories which the sub-templates may be stored within.

In some embodiments, the sub-templates may be encrypted and stored in a system memory associated with the display.

In some embodiments, the sub-templates may upon verification be decrypted and passed to a trusted execution environment (TEE) where the verification process may be carried out.

Furthermore, the number of feature points associated with the one or more stored sub-templates is associated with the enrolled user.

Hence when a user has enrolled, a number of sub-templates (at least one) comprising feature points pertaining to the fingerprint of the user will be stored and may be used in a verification (or authentication, the terms may be used interchangeably in this disclosure if nothing else is stated) process of the user.

In some embodiments, the method may further comprise repeating the steps of prompting, obtaining, forming, and storing for each of the one or more positions of the display.

In some embodiments, the steps may be repeated for only a subset of the positions.

In some embodiments, the method may further comprise determining whether a respective one or more sub-templates associated with the first position overlaps with a respective one or more sub-templates associated with the one or more positions of the display.

The method may further comprise determining a matching score between the respective one or more sub-templates associated with the first position and the respective one or more sub-templates associated with the one or more positions of the display and forming an overlap matrix, wherein the overlap matrix comprises a mapping over each sub-template's respective matching score.

The matching score may e.g. be a number between 0 and 100 and may e.g. indicate an overlap between two sub-templates. For e.g. in some embodiments a matching score in relation to two overlapping sub-templates above 50 may indicate that the two sub-templates overlaps each other with more than 50 %. In the same manner a matching score below 50 in relation to two overlapping sub-templates may indicate that two sub-templates overlap each other with less than 50 %.

Of course this is just an example, the matching score does not have to represent a percentage with which the sub-templates overlaps.

The matching score may e.g. in some embodiments indicate how often or well two or more sub-templates may be used interchangeably in order to determine a successful match.

The overlap matrix may comprise the matching scores for each of the sub-templates in relation to each other.

In some embodiments, the method may additionally or alternatively comprise determining whether a respective one or more sub-templates associated with the first position overlaps with a respective one or more other sub-templates associated with the first positions of the display.

The method may hence also comprise determining a matching between the respective one or more sub-templates associated with the first position and the respective one or more other sub-templates associated with the first position of the

display and forming an overlap matrix, wherein the overlap matrix comprises a mapping over each sub-template's respective matching score associated with the first position.

Hence the overlap matrix may comprise mappings of the matching score for all of the sub-templates in relation to each other, and/or mappings of the matching score for all sub-templates associated with one or with a subset of the positions.

If an overlap matrix comprises matching scores for one position, the method may in some embodiments comprise forming several overlap matrixes, one for each position or a respective one for a subset of positions.

In some embodiments, the one or more positions of the display, are arranged in one or more groups, wherein the one or more groups define at least one zone associated with a group of sub-templates. The sub-template of the group of sub-templates are associated with the one or more positions forming the at least one zone, and the at least one zone covers at least a part of the display.

A group of sub-templates may be a group of at least 0 sub-templates. But it may also be a group of 1, 5, 10 or any other number of sub-templates. The maximum number of sub-templates that may be comprised within a group may be determined by system limitations, such as the size of an internal memory storage.

In the same manner, a zone may comprise a group of positions, where the number of positions are at least 0 and the maximum number of positions may be determined by e.g. the resolution of the display.

In some embodiments, a zone may comprise one position associated with one sub-template, and there may be one such zone for every position of the display.

A second aspect is a method for verifying a fingerprint associated with a user and detected on a display in order to determine whether the user is an enrolled user.

The user may e.g. have been enrolled according to the method of the first aspect.

The display comprises ultrasonic sensors configured to detect fingerprints on the surface of the display. One or more positions on the display are defined, each position associated with a set of coordinates, wherein the respective set of coordinates defines where on the display the one or more positions are located.

Each of the one or more positions of the display is associated with one or more stored sub-templates comprising a number of feature points associated with a fingerprint associated with the enrolled user.

The method comprises detecting a touch occasion in a first position of the one or more positions on the display, acquiring at least one fingerprint associated with the detected touch occasion and extracting at least one feature point from the acquired at least one fingerprint.

The method may also comprise comparing the extracted at least one feature point of the acquired at least one fingerprint to one or more feature points associated with a stored first sub-template associated with the first position and determining, based on the comparison, whether the extracted at least one feature point of the acquired at least one fingerprint matches the one or more feature points associated with the stored first sub-template associated with the first position.

When it is determined that the extracted at least one feature point of the acquired at least one fingerprint matches the one or more feature points associated with the stored first sub-template the method comprises determining that the user is the enrolled user and verifying an identity of the user and authorizing the user.

In some embodiments, a successful verification and authorization may result in that the extracted feature points associated with the acquired fingerprint used for the successful verification may be stored as a further sub-template associated with the position in which the fingerprint was acquired.

Hence sub-template may be formed not only during enrollment, but also during verification. In some embodiments, when it is determined that the extracted at least one feature point of the acquired at least one fingerprint does not match the one or more feature points associated with the stored first sub-template associated with the first position the method may comprise comparing the extracted at least one feature point of the acquired at least one fingerprint to one or more feature points associated with a stored second sub-template associated with the first position.

Hence the method may iterate through the sub-templates associated with a respective position in order to determine a match between the acquired feature points and the enrolled feature points.

The method may further comprise determining based on the comparison whether the extracted at least one feature point of the acquired at least one fingerprint matches one or more feature points associated with the stored second sub-template associated with the first position.

When it is determined that the extracted at least one feature point of the acquired at least one fingerprint matches the one or more feature points associated with

the stored second sub-template associated with the first position the method may comprise determining that the user is the enrolled user and verifying the identity of the user and authorizing the user.

Furthermore, in some embodiments, when it is determined that the extracted at least one feature point of the acquired at least one fingerprint does not match the one or more feature points associated with the at least one stored second sub-template associated with the first position the method may comprise comparing the extracted at least one feature point of the acquired at least one fingerprint to one or more feature points associated with at least one stored sub-template associated with at least one second position.

Hence, when all sub-templates of a first position has been compared to the acquired feature points and no match was determined, the method may compare with one or more sub-templates associated with at least one second (i.e. with one or more other) position of the display.

The method may comprise determining based on the comparison whether the extracted at least one feature point of the acquired at least one fingerprint matches one or more feature points associated with the at least one stored sub-template associated with the at least one second position.

In some embodiments, when it is determined that the extracted at least one feature point of the acquired at least one fingerprint does not match one or more feature points associated with the at least one stored sub-template associated with the at least one second position the method may further comprise comparing the extracted at least one feature point of the acquired at least one fingerprint to each of the one or more feature points associated with each of the stored sub-templates associated with each of the one or more positions of the display until a match is found, or until each of the feature points associated with each of the stored sub-templates associated with each of the one or more positions of the display has been compared to the extracted at least one feature point of the acquired at least one fingerprint.

Hence the method may comprise iterating through all stored sub-templates associated with each of the positions of the display in order to find a sub-template that matches the acquired feature points and verify the user.

However, when it is determined that no match is found after comparing the extracted at least one feature point of the acquired at least one fingerprint to each of the one or more feature points associated with each of the stored sub-templates associated

with each of the one or more positions of the display the method may comprise determining that the user is not the enrolled user and denying authorization to the user.

In some embodiments, the method may comprise determining that the user is not the enrolled user when all sub-templates associated with the position in which the touch occurred has been compared to the extracted feature points, or when all sub-templates associated with a sub-set of positions has been compared.

The determination of how many sub-templates should be iterated through when performing verification may be based on system parameters such as available processing resources, working memory, speed of verification, etc.

In some embodiments, when the verification process results in that a user is not authorized, the method may further comprise prompting the user to touch the display again but at a different position.

In some embodiments, each stored sub-template associated with each of the one or more positions of the display is associated with a popularity score, wherein a sub-template having a high popularity score is indicative of that the sub-template is used more often for successful authorization of the user than a sub-template having a low popularity score.

The popularity score may e.g. be a number between 0 and 100, where 100 indicates 100% successful matching and 0 indicates 0 successful matching. What is seen as a high or a low popularity score may be relative and be based on e.g. the number of total matching attempts and their result. Hence in some scenarios, a popularity score of 20 may be regarded as high, if the next highest score is 10, whereas in some scenarios a popularity score of 40 may be regarded as low if the highest score is 70.

The popularity score may also be indicated by something else than a number, what is important is that the scores may be ranked for the sub-templates in relation to each other.

In some embodiments, a stored sub-template associated with the first position in which the touch occasion occurred associated with a highest popularity score among the popularity scores associated with each of the at least one stored sub-templates associated with the first position is used first in order to determine if the user is the enrolled user. The method may e.g. comprise comparing the at least one extracted feature point of the acquired fingerprint to the one or more feature points associated with the stored sub-template associated with the highest popularity score associated with the first position.

Hence when performing verification, the method may comprise determining which of the sub-templates stored for a certain position that has the highest popularity score in relation to the other sub-templates associated with the position, and chose the sub-template with the highest popularity score for the first verification attempt.

Since the highest popularity score indicates that the sub-template is used most often for successful verification, using this sub-template first may have a higher probability in resulting in an instant match which may save time and computer resources when performing verification.

In some embodiments, if it is determined that the user is not the enrolled user when comparing the one or more feature points associated with the stored sub-template associated with the highest popularity score associated with the first position to the extracted at least one feature point of the acquired at least one fingerprint, the method further comprises comparing the at least one feature point to each of the stored sub-templates associated with the highest popularity score associated with each of the one or more positions of the display.

Hence, the method may comprise that the sub-templates associated with the highest popularity scores for each position are used first in the verification process before comparing to the rest of the sub-templates.

E.g. in an example scenario there are three positions comprising two sub-templates each. Position 1 is associated with sub-templates 1a and 2a having a respective popularity score of 20 and 70. Position 2 is associated with sub-templates 1b and 2b having a respective popularity score of 25 and 32. Position 3 is associated with sub-templated 1c and 2c having a respective popularity score of 55 and 10.

As an example, when performing a verification where a touch occurred in position 2, sub-template 2b may be used for the first comparison and verification attempt (since it has the highest score of position 2). If the sub-template 2b does not yield a match then the sub-templates may be compared in the following order: 2a, 1c, 1b, 1a, and 2c, hence the sub-templates having the highest scores for each position may be checked first prior to checking the other sub-templates for each of the position. In this example the other sub-templates has been checked in a declining order, but other orders are possible.

According to some embodiments, if all sub-templates for a certain position should be checked first, then the following order may be used if the touch occurred in position 2: 2b, 1b, 1c, 2c, 2a, and 1a. It should be noted that the order of the positions

may vary. Hence position 1 may be checked before position 3 in some embodiments, if the touch occurred in position 2.

Furthermore, in some embodiments, a stored sub-template associated with a highest popularity score among the popularity scores associated with each of the stored sub-templates associated with each of one or more positions of the display is used first in order to determine if the user is the enrolled user.

Returning to the above example, in this scenario, regardless of in which position the touch occurred, sub-template 2a would be used first.

In some embodiments, if sub-template 2a is used first and this results in an unsuccessful verification, the following order of the sub-templates may be used: 1c, 2b, 1b, and 1a, 2c.

It is to be noted that these orders are just examples, and other orders are contemplated, such as e.g. the order 2b, 1b, 2a, 1c, 1a, 2c indicating that all sub-templates associated with the position in which the touch occurred are used first and then the remaining sub-templates in a declining order according to their matching score is used if a successful authorization is not achieved.

In some embodiments the method may further comprise an overlap matrix comprising a mapping over each of the stored sub-templates, wherein each of the stored sub-templates are associated with a matching score between each of the stored sub-templates in relation to each other.

The overlap matrix may e.g. have been formed during the enrollment process described in the method according to the first aspect.

In some embodiments, the method may comprise adding the extracted at least one feature point to the overlap matrix and determining a matching score of the extracted at least one feature point in relation to each of the stored sub-templates in the overlap matrix and comparing the extracted at least one feature point to a sub-template associated with the first position having a highest matching score in relation to the extracted at least one feature point.

The extracted at least one feature point may e.g. be associated with a verification template which may be added or to used in the overlap matrix. The verification template may comprise the at least one extracted feature point.

When it is determined that the extracted at least one feature point of the acquired at least one fingerprint does not match the one or more feature points associated with the sub-template associated with the first position having the highest

matching score in relation to the extracted at least one feature point, the method may comprise determining whether the overlap matrix comprises at least one sub-template associated with a matching score which exceeds a matching threshold in relation to the sub-template associated with the first position having the highest matching score in relation to the extracted at least one feature point..

The matching threshold may be dynamically set and may be based on parameters such as available computer and/or processing resources, size of internal memory, speed requirements of the verification process etc.

The matching threshold may e.g. indicate how high the matching score between the extracted feature point and a stored sub-template should be in order to use the sub-template in the verification process.

Hence, in some embodiments, the matching threshold may be used for determining whether a sub-template associated with e.g. the position in which the touch occurred may be used for performing verification against the at least one extracted feature point. If e.g. the matching threshold is set to 30 and there are no sub-templates associated with the position in which the touch occurred that has a matching score of 30 or above in relation to the at least one extracted feature point, then the method may comprise determining whether the overlap matrix comprises any other sub-template having a matching score equal to or higher than the matching threshold, and if so, perform verification by means of least one of those sub-templates.

Then the method may comprise comparing the extracted at least one feature point to one or more feature points associated with the at least one sub-template associated with the matching score which exceeds the matching threshold in relation to the sub-template associated with the first position having the highest matching score in relation to the extracted at least one feature point and determining based on the comparison whether the extracted at least one feature point of the acquired at least one fingerprint matches one or more feature points associated with the at least one sub-template associated with the matching score which exceeds the matching threshold in relation to the sub-template associated with the first position having the highest matching score in relation to the extracted at least one feature point.

If no match is found (i.e. the verification was un-successful when comparing to the sub-template having the highest matching score in the first position) then the method may comprise comparing the extracted feature points to the one or more feature points associated with at least one sub-template associated with a matching score which

exceeds the matching threshold in relation to the sub-template associated with the first position having the next-highest matching score in relation to the extracted feature point.

The procedure may then be iterated through the sub-templates of the overlap matrix either associated with the first position (i.e. the position in which the touch occurred) or with other positions of the display, until a match is found.

Hence when performing verification, sub-templates associated either with the same position as the touch occurred or in other positions which may comprise feature points that overlap with the acquired feature points may be quickly found and used for the verification process in order to find a positive match as quick as possible.

In some embodiments, the overlap matrix may also be updated when a successful authorization has occurred, such that extracted feature points (which may have been formed into a verification template for performing matching against the sub-templates of the overlap matrix) are added to the overlap matrix as a new sub-template and associated with the matching score of the extracted feature points in relation to the other stored sub-templates.

A third aspect is an arrangement (or system) configured to enroll and verify fingerprints of a user. The arrangement may be configured to be associated with a display wherein the display comprises ultrasonic sensors configured to detect fingerprints on the surface of the display.

One or more positions on the display are defined, each position associated with a respective set of coordinates, wherein the respective set of coordinates defines where on the display the one or more positions are located.

The arrangement comprises a controller configured to cause association of at least one of the one or more positions with at least one sub-template associated with one or more feature points associated with a fingerprint of the user.

In some embodiments, the controller is further configured to cause an enrollment process of the user by causing prompting of the user to touch a first position associated with a first set of coordinates of the display one or more times and detection of at least one touch occasion in the first position of the display wherein each touch occasion results in a respective fingerprint.

The controller may also be configured to cause extraction of a number of feature points from each respective fingerprint, formation of one or more sub-templates comprising the number of feature points associated with the respective fingerprint and

associating the one or more sub-templates with the first position by storing information pertaining to the first set of coordinates in the sub-template.

The controller may further be configured to cause storing the one or more sub-templates associated with the first position, wherein the number of feature points associated with the one or more stored sub-templates is associated with the enrolled user.

In some embodiments, the controller is further configured to cause repetition of the steps of prompting, obtaining, forming, and storing for each of the one or more positions of the display.

In some embodiments, the controller is further configured to cause determination of whether a respective one or more sub-templates associated with the first position overlaps with a respective one or more sub-templates associated with the one or more positions of the display and cause determination of a matching score between the respective one or more sub-templates associated with the first position and the respective one or more sub-templates associated with the one or more positions of the display.

The controller may be further configured to cause formation of an overlap matrix, wherein the overlap matrix comprises a mapping over each sub-template's respective matching score.

In some embodiments, the controller may additionally or alternatively be configured to cause determination of whether a respective one or more sub-templates associated with the first position overlaps with a respective one or more other sub-templates associated with the first positions of the display.

In some embodiments, the controller may be configured to cause determination of a matching score between the respective one or more sub-templates associated with the first position and the respective one or more other sub-templates associated with the first position of the display and cause formation of an overlap matrix, wherein the overlap matrix comprises a mapping over each sub-template's respective matching score associated with the first position.

In some embodiments, the controller is further configured to cause arranging of the one or more positions on the display into one or more groups. The one or more groups defines at least one zone associated with a group of sub-templates, wherein the sub-templates of the group of sub-templates are associated with the one or more

positions forming the at least one zone, and wherein the at least one zone covers at least a part of the display.

In some embodiments, the controller is further configured to cause a verification process of a fingerprint associated with a second user detected on the display in order to determine that the second user is the enrolled user, by causing detection of a touch occasion in a first position of the one or more positions of the display and causing acquisition of at least one fingerprint associated with the detected touch occasion.

The controller may be further configured to cause extraction of at least one feature point from the acquired at least one fingerprint and cause comparison of the extracted at least one feature point of the acquired at least one fingerprint to one or more feature points associated with a stored first sub-template associated with the first position.

In some embodiments, the controller is configured to, based on the comparison, cause determination of whether the extracted at least one feature point of the acquired at least one fingerprint matches the one or more feature points associated with the stored first sub-template associated with the first position.

When it is determined that the extracted at least one feature point of the acquired at least one fingerprint matches the one or more feature points associated with the stored first sub-template, the controller is configured to cause determination of that the second user is the enrolled user and cause verification of an identity of the second user and authorization of the second user.

In some embodiments, the controller is further configured to cause, when it is determined that the extracted at least one feature point of the acquired at least one fingerprint does not match the one or more feature points associated with the stored first sub-template associated with the first position comparison of the extracted at least one feature point of the acquired at least one fingerprint to one or more feature points associated with a stored second sub-template associated with the first position.

The controller may be further configured to cause determination of, based on the comparison, whether the extracted at least one feature point of the acquired at least one fingerprint matches one or more feature points associated with the stored second sub-template associated with the first position.

When it is determined that the extracted at least one feature point of the acquired at least one fingerprint matches the one or more feature points associated with

the stored second sub-template associated with the first position the controller may be configured to cause determination of that the second user is the enrolled user and cause verification of the identity of the second user and authorization of the second user.

In some embodiments, the controller is further configured to cause, when it is determined that the extracted at least one feature point of the acquired at least one fingerprint does not match the one or more feature points associated with the at least one stored second sub-template associated with the first location comparison of the extracted at least one feature point of the acquired at least one fingerprint to one or more feature points associated with at least one stored sub-template associated with at least one second position.

The controller may also be configured to cause determination of, based on the comparison, whether the extracted at least one feature point of the acquired at least one fingerprint matches one or more feature points associated with the at least one stored sub-template associated with the at least one second position.

In some embodiments, the controller is further configured to cause, when it is determined that the extracted at least one feature point of the acquired at least one fingerprint does not match one or more feature points associated with the at least one stored sub-template associated with the at least one second position comparison of the extracted at least one feature point of the acquired at least one fingerprint to each of the one or more feature points associated with each of the stored sub-templates associated with each of the one or more positions of the display until a match is found, or until each of the feature points associated with each of the stored sub-templates associated with each of the one or more positions of the display has been compared to the extracted at least one feature point of the acquired at least one fingerprint.

In some embodiments, the controller is further configured to cause, when it is determined that no match is found after comparing the extracted at least one feature point of the acquired at least one fingerprint to each of the one or more feature points associated with each of the stored sub-templates associated with each of the one or more positions of the display, determination of that the second user is not the enrolled user; and cause denial of authorization of the second user.

In some embodiments, the controller is further configured to cause association of each stored sub-template associated with each of the one or more positions of the display with a popularity score, wherein a sub-template associated with a high popularity score is indicative of that the sub-template is used more often for successful

authorization of the enrolled user than a sub-template associated with a low popularity score.

In some embodiments, a stored sub-template associated with the first position in which the touch occasion occurred associated with a highest popularity score among the popularity scores associated with each of the at least one stored sub-templates associated with the first position is used first in order to determine if the second user is the enrolled user by comparing the at least one extracted feature point of the acquired fingerprint to the one or more feature points associated with the stored sub-template associated with the highest popularity score associated with the first position.

In some embodiments, if it is determined that the second user is not the enrolled user when comparing the one or more feature points associated with the stored sub-template associated with the highest popularity score associated with the first position to the extracted at least one feature point of the acquired fingerprint, the controller is further configured to cause comparison of the at least one feature point to each of the stored sub-templates associated with the highest popularity score associated with each of the one or more positions of the display.

In some embodiments, a stored sub-template associated with a highest popularity score among the popularity scores associated with each of the stored sub-templates associated with each of one or more positions of the display is used first in order to determine if the second user is the enrolled user.

In some embodiments the controller is further configured to cause addition of the extracted at least one feature point to the overlap matrix (e.g. by forming a verification template comprising the extracted at least one feature point) and determining a matching score of the extracted at least one feature point in relation to each of the stored sub-templates in the overlap matrix. The controller may also be configured to cause comparison of the extracted at least one feature point to a sub-template associated with the first position having a highest matching score in relation to the extracted at least one feature point.

When it is determined that the extracted at least one feature point of the acquired at least one fingerprint does not match the one or more feature points associated with the sub-template associated with the first position having the highest matching score in relation to the extracted at least one feature point, the controller is further configured to cause determination of whether the overlap matrix comprises at least one sub-template associated with a matching score which exceeds a matching

threshold in relation to the sub-template associated with the first position having the highest matching score in relation to the extracted at least one feature point.

When it is determined that the overlap matrix comprises at least one sub-template associated with a matching score which exceeds a matching threshold in relation to the sub-template associated with the first position having the highest matching score in relation to the extracted at least one feature point the controller is configured to cause comparison of the extracted at least one feature point to one or more feature points associated with the at least one sub-template associated with the matching score which exceeds the matching threshold in relation to the sub-template associated with the first position having the highest matching score in relation to the extracted at least one feature point and cause determination based on the comparison whether the extracted at least one feature point of the acquired at least one fingerprint matches one or more feature points associated with the at least one sub-template associated with the matching score which exceeds the matching threshold in relation to the sub-template associated with the first position having the highest matching score in relation to the extracted at least one feature point.

A fourth aspect is an electronic device comprising the arrangement according to the third aspect.

The electronic device may e.g. be a mobile phone, a smart phone, a wireless communication device, a computer, a lap top, a smart card, a digital display, smart-board such as an interactive white board, etc.

A fifth aspect is a computer program product comprising a non-transitory computer readable medium, wherein the computer readable medium has stored there on a computer program comprising program instructions.

The computer program is configured to be loadable into a data-processing unit, comprising a processor and a memory associated with or integral to the data-processing unit, wherein when loaded into the data-processing unit, the computer program is configured to be stored in the memory. The computer program, when loaded into and run by the processor is configured to cause the processor to execute method steps according to any of the first and second aspects.

In some embodiments, any of the above aspects may additionally have features identical with or corresponding to any of the various features as explained above for any of the other aspects.

An advantage of some of the embodiments described herein is that they enable either or both of an enrollment process and a verification process of biometric data which is fast and/or robust.

Another advantage of some of the embodiments is that by means of the methods and arrangement described herein ensures that the enrollment and verification process takes into consideration technical features of the ultrasonic sensor technology for acquiring fingerprints.

Another advantage of some embodiments is that by storing sub-templates comprising feature points from one or more fingerprints and associating the sub-templates to the positions of the display in which the fingerprints were acquired it is taken into consideration that the extracted feature points pertaining to the same finger may retain different characteristics based on where on the display they were acquired due to the ultrasonic sensors.

Another advantage of some embodiments is hence that the enrollment and verification process is not affected and will still be reliable for in-display acquisition.

Another advantage of some embodiments is that the methods and arrangement enables collecting and storing a relatively large amount of sub-templates while still keeping the complexity and processing demands of the verification process low leading to that the verification process will be quick and simple.

**Brief Description of the Drawings**

Further objects, features, and advantages will appear from the following detailed description of embodiments, with reference being made to the accompanying drawings, in which:

Fig. 1 is a flowchart illustrating example method steps according to some embodiments;

Fig. 2 is a flowchart illustrating example method steps according to some embodiments;

Fig. 3 is a flowchart illustrating example method steps according to some embodiments

Fig. 4 is a schematic drawing illustrating an example enrollment/verification scheme according to some embodiments;

Fig. 5 is a schematic drawing illustrating an example enrollment/verification scheme according to some embodiments;

Fig. 6 is a block diagram illustrating an example arrangement according to some embodiments; and

Fig. 7 is a schematic drawing illustrating a computer program product according to some embodiments.

**Detailed Description**

In the following, embodiments will be described where a fast and robust enrollment and verification process is enabled for in display fingerprint acquisition using ultrasonic technology.

As previously mentioned, due to the physical behavior of ultrasound scattering and the system limitations in terms of the number of transducer elements (transmitters as well as receivers) and the positions of these, the system can become sensitive to where on the display the acquisition takes place.

Hence, it is likely to assume that this results in slightly different image representations of the same fingerprint depending on where the finger is touching the display, especially near the edges of the display.

Although a well-designed enrollment scheme can compensate for this in terms of FRR (false rejection rate) performance, the time it takes to perform a matching attempt scales with the number of enrolled sub-templates needed to make a robust solution that handles these differences.

In order to cope with the differences that cannot be compensated for by e.g. calibration and echo cancelling, the enrollment scheme should preferably store information with regards to where on the display the user has touched it, with the preference being information obtained from all possible locations. This way, the enrolled acquisition data (also denoted sub-templates in this disclosure) will contain additional information related to the representations/variations of the fingerprint.

To obtain a good FRR performance in all parts of the display, each part of the display may preferably be represented by at least one touch during enrollment. In summary, this leads to a high number of enroll sub-templates to be matched against in each verify attempt, which would furthermore scale with the display size.

Besides addressing the enrollment procedure, care may also be taken to improve the matching time in case of a genuine identification attempt. This may e.g. be done by adaptively ordering all the enrolled sub-templates according to the location of

the finger as well as information from the matching against the first part of the sub-templates.

Fig. 1 illustrates a method 100 for enrolling a fingerprint associated with a user and detected on a display in order to enroll the user according to some embodiments.

The display may in some embodiments comprise ultrasonic sensors configured to detect fingerprints on the surface of the display. Furthermore, one or more positions on the display are typically defined, wherein each position is associated with a respective set of coordinates. The respective set of coordinates may define where on the display the one or more positions are located.

It should be noted that in this disclosure, the terms "position" and "location" may be used interchangeably unless otherwise stated.

The method 100 may start in step 110 with prompting the user to touch a first position on the display associated with a first set of coordinates one or more times.

When enrolling a fingerprint, a process may be initiated which tells the user to start the enrollment by touching the screen, either on a predetermined location, or on a location of the user's choosing. This may be communicated e.g. by means of pop ups comprising text on the display, or by a voice recording being played for the user or by any other suitable means.

The method continues in step 120 with detecting at least one touch occasion in the first position of the display wherein each touch occasion results in a respective fingerprint. Thus, in step 130 the display registers a touch and acquires the fingerprint which resulted from the touch.

In step 140 the method continues with extracting a number of feature points from each respective fingerprint.

By only extracting a number of feature points instead of the whole fingerprint, (which would also be possible) computer processing is decreased and it becomes less cumbersome to register fingerprints.

Then in step 150 one or more sub-templates are formed comprising the number of feature points extracted from the respective fingerprint and the one or more sub-templates are associated with the first position by information pertaining to the first set of coordinates being stored in the sub-template.

The method continues in step 160 with storing the one or more sub-templates associated with the first position, wherein the number of feature points associated with the one or more stored sub-templates is associated with the enrolled user.

Hence, when enrolling a fingerprint, a user may be instructed to touch the display one or more times, wherein each touch may result in one or more sub-templates associated with the location in which the touch occurred.

This may typically ensure that when verification is made, it won't matter where on the display the fingerprint to be verified was detected, since there may be a sub-template stored for this location. Hence verification may be made against that particular sub-template.

In some embodiments, the method 100 may further comprise repeating the steps of prompting, obtaining, forming and storing for each of the one or more positions of the display.

Hence, the enrollment process may comprise obtaining at least one sub-template for every possible location on the display. In some embodiments, the method may comprise obtaining a sub-template for at least a subset of the one or more locations of the display.

In some embodiments, the above described enrollment process may be initiated as a first time procedure e.g. if the user gives a password for enrollment or similar. However, if the enrollment process is not initiated, the display may detect fingerprints and determine that the detected fingerprints should be verified (i.e. the identity of the fingerprint holder should be authenticated).

Hence a verification process may also typically be performed in addition to the enrollment process.

Fig. 2 illustrates a method 200 for verifying a fingerprint associated with a user and detected on a display in order to determine whether the user is an enrolled user.

The user may e.g. earlier have enrolled its fingerprint according to the method 100 described in Fig. 1.

The display comprises ultrasonic sensors configured to detect fingerprints on the surface of the display. The display may e.g. be the display described in conjunction with Fig. 1.

One or more positions on the display may be defined, each position being associated with a set of coordinates. The respective set of coordinates may define where on the display the one or more positions are located. Furthermore, each of the one or more positions of the display is associated with one or more stored sub-templates (compare with the method 100) comprising a number of feature points associated with a fingerprint associated with the enrolled user.

The method 200 starts in 210 with detecting a touch occasion in a first position of the one or more positions on the display. I.e. a person is touching the display somewhere on the surface.

Then the method continues in 220 with acquiring at least one fingerprint associated with the detected touch occasion and in 230 extracting at least one feature point from the acquired at least one fingerprint (compare the steps 210-230 e.g. with the steps 120-140 of the method 100).

Then in step 240 the method comprises comparing the extracted at least one feature point of the acquired at least one fingerprint to one or more feature points associated with a stored first sub-template associated with the first position.

Then in step 250 it is determined, based on the comparison, whether the extracted at least one feature point of the acquired at least one fingerprint matches the one or more feature points associated with the stored first sub-template associated with the first position.

When it is determined that the extracted at least one feature point of the acquired at least one fingerprint matches the one or more feature points associated with the stored first sub-template (Y-path out of 250), the method continues in 260 with determining that the user is the enrolled user and verifying an identity of the user and authorizing the user.

In some embodiments, a successful authorization may result in that the extracted feature points associated with the acquired fingerprint used for successful match may be optionally stored in step 270 as a further sub-template associated with the position in which the fingerprint was acquired.

Hence the sub-templates may be formed both during the enrollment process described in conjunction with Fig. 1, but also during the verification process as described in conjunction with Fig. 2.

When in 250 it is determined that the extracted at least one feature point of the acquired at least one fingerprint does not match the one or more feature points associated with the stored first sub-template associated with the first position (N-path out of 250), the method continues in 280 where it is determined whether the first location comprises other stored sub-templates.

In some embodiments, this step may be omitted and the method may instead comprise iterating by default through all available sub-templates of a certain location until a match is found or until there are no more sub-templates.

It may e.g. be that the first stored sub-template associated with the first position is of inferior quality or that the detected touch was somehow different with regards to the touch which resulted in the stored sub-template. In such case the method may comprise checking whether the first position (i.e. the location which the fingerprint was acquired from) comprises more than the first sub-template and use one or more of these for trying to verify the acquired fingerprint.

Returning to the method 200, when it is determined in 280 that there are other sub-templates stored for the first position (Y-path out of 280) the method may return to step 240 with comparing the extracted at least one feature point of the acquired at least one fingerprint to one or more feature points associated with a stored second sub-template associated with the first position.

The step 250 may then be performed again but for the stored second sub-template, and when it is determined that the extracted at least one feature point of the acquired at least one fingerprint matches the one or more feature points associated with the stored second sub-template associated with the first position (Y- path out of 250) the method continues in 260 with determining that the user is the enrolled user and verifying the identity of the user and authorizing the user.

It should be noted that the step 240-280 may be iterated for each of the stored sub-templates associated with the first position until a match is found or until there are no more sub-templates.

In some embodiments, the method 200 may, when it is determined that the extracted at least one feature point of the acquired at least one fingerprint does not match the one or more feature points associated with the at least one stored second sub-template associated with the first position, further comprise comparing the extracted at least one feature point of the acquired at least one fingerprint to one or more feature points associated with at least one stored sub-template associated with at least one second position.

The method may e.g. comprise determining that there was no match (N-path out of 250), determine whether a sub-template associated with a second position is available (step 280) and compare to the sub-template associated with the second position (step 240) if it is determined to be available (Y-path out of 280).

Hence, if none of the sub-templates associated with the first position (i.e. the position where the touch occurred) the method may comprise matching the acquired

fingerprint against one or more sub-templates associated with another position of the screen. This may e.g. be a neighbouring position, or any other suitable position.

The method 200 may also comprise determining based on the comparison whether the extracted at least one feature point of the acquired at least one fingerprint matches one or more feature points associated with the at least one stored sub-template associated with the at least one second position.

Hence the method 200 may be carried out for other positions aside from just the position where the fingerprint was actually acquired.

In some embodiments, when it is determined that the extracted at least one feature point of the acquired at least one fingerprint does not match one or more feature points associated with the at least one stored sub-template associated with the at least one second position, the method 200 may further comprise comparing the extracted at least one feature point of the acquired at least one fingerprint to each of the one or more feature points associated with each of the stored sub-templates being associated with each of the one or more positions of the display until a match is found, or until each of the feature points associated with each of the stored sub-templates associated with each of the one or more positions of the display has been compared to the extracted at least one feature point of the acquired at least one fingerprint.

Hence, all sub-templates of all possible positions of the display may be checked and compared by means of the method 200 to the acquired fingerprint in order to find a match.

In some embodiments, when it is determined that no match is found after comparing the extracted at least one feature point of the acquired at least one fingerprint to each of the one or more feature points associated with each of the stored sub-templates associated with each of the one or more positions of the display it may be an indication that the user is not enrolled (N-path out of 280). The method 200 may then continue in 290 with determining that the user is not the enrolled user and denying authorization to the user.

In some embodiments, in order to further enhance and speed up the verification process a popularity score may be introduced.

This is illustrated by the method 300 of Fig. 3.

In some embodiments, the method 300 may be combined with the method 200.

The method 300 may start in step 310 with detecting a touch (compare with step 210 of the method 200, step 310 may hence be the same as step 210).

Then the method continues in step 320 with acquiring a fingerprint from the detected touch (compare with step 220 in the method 200 which may hence be the same step as 220.)

Then the method continues in 330 with extracting feature points of an acquired fingerprint (compare with step 230 of the method 200, step 330 and step 230 may hence be the same if the methods were to be combined).

In step 340, the method continues with comparing the extracted feature points of the acquired fingerprint to one or more feature points of the sub-template associated with the first position having the highest popularity score (compare with step 240 of the method 200).

For example, in some embodiments each stored sub-template associated with each of the one or more positions of the display is associated with a popularity score. A sub-template having a high popularity score is indicative of that the sub-template is used more often for successful authorization of the user than a sub-template having a low popularity score.

The popularity score may e.g. be a number, an integer, a code representation or any other suitable representation to indicate number of times the sub-template was used for successful authorization.

What is seen as a high score may be relative to the score of the other sub-templates. For example, if there is a total of 5 stored sub-templates, and one of these has a score of 6 whereas the others only have a score of 2 or lower, then the sub-template having the score of 6 will be regarded to have a high popularity score. It may e.g. be determined that the sub-template which has the highest score is the most popular one. E.g. if the highest score is 6 and the next highest is 5, then the score or 6 will be determined to be the highest and thus the most popular one.

In some embodiments, a stored sub-template associated with the first position in which the touch occasion occurred which sub-template is associated with a highest popularity score among the popularity scores associated with each of the at least one stored sub-templates associated with the first position is used first in order to determine if the user is the enrolled user. For example by comparing the at least one extracted feature point of the acquired fingerprint to the one or more feature points associated with the stored sub-template associated with the highest popularity score associated with the first position, as described in step 340.

Hence, when performing the method 300 the first sub-template which is used for determining whether the user is the enrolled user is the sub-template which has the highest popularity scored compared to the other sub-templates stored for the first position. Using the sub-template with the highest score increases the chances that a match will be made after the first comparison, which saves time and processing resources.

If in 350 it is determined that there is a match with the sub-template having the highest score associated with the first position (Y-path out of 350), the method continues in 351 with authorizing the user, and in 352 the popularity score for the successful sub-template is increased.

In the same manner, in some embodiments, if it is determined that the user is not the enrolled user when comparing the one or more feature points associated with the stored sub-template associated with the highest popularity score associated with the first position to the extracted at least one feature point of the acquired at least one fingerprint (N-path out of 350), the method may further comprise determining in 360 whether a sub-template having a highest popularity score associated with any other position is available (i.e. if there are any other sub-templates stored for any other location).

If so (Y-path out of 360) the method may continue with comparing in step 361 the at least one feature point to each of the stored sub-templates associated with the highest popularity score associated with each of the one or more positions of the display.

Hence, instead of checking the rest of the stored sub-templates associated with the first position if no match was found based on the stored sub-template having the highest score for the first position, the method may comprise directly comparing the acquired fingerprint with the stored sub-templates having the highest scores associated with each of the other positions of the display.

In some embodiments, the method may comprise checking the rest of the stored sub-templates associated with the first position prior to checking any sub-template associated with each of the other positions of the display.

However, if the other sub-templates have a high score and often result in successful authorization it may be that a match is found more quickly when comparing to those sub-templates than when comparing to the ones being associated with the correct position, but having a low score.

It may also be contemplated that in some embodiments a stored sub-template associated with a highest popularity score among the popularity scores associated with each of the stored sub-templates associated with each of one or more positions of the display is used first in order to determine if the user is the enrolled user.

Hence the method 300 may comprise determining which of all of the stored sub-templates (for all positions) that has the highest score, and always using this sub-template first when comparing to an acquired fingerprint, regardless of the position of where the fingerprint was acquired.

In some embodiments when all of the sub-templates associated with each of the positions of the display having the highest popularity score has been compared against the acquired fingerprint, and no match has been made (N-path out of 360) the method 300 may further comprise determining in 370 whether there are any other sub-templates available for any position, and if so (Y-path out of 370) the method may continue in 371 with comparing the acquired fingerprint to the remaining sub-templates.

Or, if is determined that no other sub-templates are available for any position, the method may continue in 372 with denying authorization of the user since no successful match could be made.

In some embodiments, the most general case of positions and sub-templates may be that every possible coordinate of the display may be associated with a position, and each of these positions may comprise or be associated with one or more stored sub-templates.

However, in some embodiments, the one or more positions of the display may be arranged in one or more groups.

The one or more groups may define at least one zone associated with a group of sub-templates. The sub-templates of the group of sub-templates are associated with the one or more positions forming the at least one zone. The at least one zone may in some embodiments cover at least a part of the display.

This is illustrated in Fig. 4. Fig. 4 shows a display 410 which has been divided into a number of zones 410a-410h.

The display 410 may e.g. be the display described in conjunction with any of the previous figures, and may comprise circuitry configured to carry out the method according to any of the previous figures.

Each zone may comprise one or more positions having coordinates which falls within the zone border.

Hence all touches that are located within e.g. the borders of zone 410a will be associated to zone 410a and so will the sub-templates that result from each of those touches.

Thus, zone 410a may comprise a group of sub-templates which may be used for comparison when a touch is detected anywhere within the zone 410a.

As an example, in Fig. 4, a fingerprint 420 is acquired in zone 410f, the fingerprint having XY coordinates 421 that are within the zone 410f borders.

When authorizing the fingerprint 420, all sub-templates which has previously been enrolled for all coordinates which falls within the borders of the zone 410 f may be used.

It should be noted that although Cartesian coordinates have been used as an example in Fig. 4 other types of coordinates are possible, such as polar.

Furthermore, the division into zones may take other appearances than the grid of Fig. 4. It is e.g. possible with a fewer or greater number of zones, zones divided in a circular manner, zones divided into triangles, ellipses, oblongs etc. The appearance of the zone division may dependent on parameters such as wave propagation of the ultrasound, setup of the ultrasound transducers, type of display, size of display etc.

In order to further increase the speed and robustness of the verification process, overlapping sub-templates associated with one or more positions may be arranged in an overlap matrix.

For example, Fig. 5 illustrates a display 500 where a at least one fingerprint is acquired during an enrollment process (e.g. the enrollment process described by the method 200 in Fig. 2) in a first zone (for simplicity in the example the three different touches are denoted as the first touch resulting in a first fingerprint), zone A (or a first position). The first fingerprint acquisition may have resulted in several touches with extracted feature points associated with each touch and located on three different spots of the fingerprint, which in turn has leads to three different sub-templates 511, 512 and 513 associated with the location of the fingerprint 510.

In some embodiments, a single touch may result in one or more sub-templates. Hence in the example of Fig. 5 it is contemplated that the three sub-templates 511-513 all stems from the same touch occasion.

Then, during the enrollment process, the user may touch the display again at least one time, this time at another position located in zone B. The touches may result in a second fingerprint 520 (for simplicity only one fingerprint, denoted as the second

fingerprint, is shown in this example, but the number of prints may of course in some embodiments correspond to the number of touches). In this example, three sub-templates 521, 522, 523 are formed based on the feature points of the second fingerprint 520 (hence three touches may have occurred, resulting in three different fingerprints and sub-templates).

For simplicity, the sub-templates 511-513 are formed by the same feature points that form the sub-templates 521-523, however it should be noted that different feature points may be extracted for different touches.

As can be seen in Fig. 5, in zone A sub-template 513 is slightly overlapped by sub-templates 511 and 512. Correspondingly sub-template 523 is slightly overlapped by sub-templates 521-522.

The overlap matrix may then be formed according to the following table where 531 indicates the extracted feature points of the acquired fingerprint (stored e.g. in the form of a verification template) which is to be verified against the stored sub-templates of zone A e.g. based on their associated matching score in relation to the extracted feature points.

Zone A overlap matrix (for simplicity in this example, the matrix for Zone B is equal to that of Zone A since the sub-templates are acquired from the same feature points of the fingerprint, it is to be noted that in a real-life example the matrix of Zone A would presumably not exactly resemble the matrix of Zone B due to e.g. rotation of fingerprint pressure when applied and ultrasound propagation):

| | 511 (521) | 512 (522) | 513 (523) |
|---|---|---|---|
| 511 (521) | 100 | 25 | 1 |
| 512 (522) | 25 | 100 | 30 |
| 513 (523) | 1 | 30 | 100 |
| 531 | 0 | 10 | 50 |

It should be noted that these numbers are only exemplary.

The overlap matrix illustrates match scores, which scores does not have to coincide with the respective overlap. The matching scores may e.g. be determined over time and updated with each successful authorization. In some embodiments, the matching scores may be initially predicted based on the overlap of the sub-templates and/or extracted feature points of a fingerprint.

The matrices which would result from the sub-templates of Fig 5 may e.g. illustrate matching scores which coincide with the overlap of the sub-templates. Thus, 511 and 512 overlaps by 25%; 511 and 513 overlaps by 1%; 512 and 513 overlaps by 30%. Naturally, 511, 512, and 513 each overlap itself by 100%, respectively. The matching score may indicate how high the probability is that successful authorization will result if substituting one sub-template with another from the overlap matrix, when matching against the extracted feature points.

Hence, the matching score between two or more sub-templates may in some embodiments alternatively or additionally also indicate how high the probability is that successful authorization will be achieved if comparing to a second sub-template when the comparing to the first failed.

When combining zone A and zone B the Global overlap matrix looks as follows: (contains Zone A and Zone B plus the inter-relation):

| | 511 | 512 | 513 | 521 | 522 | 523 |
|---|---|---|---|---|---|---|
| 511 | 100 | 25 | 1 | 90 | 23 | 0 |
| 512 | 25 | 100 | 30 | 23 | 90 | 27 |
| 513 | 1 | 30 | 100 | 0 | 27 | 90 |
| 521 | 90 | 23 | 0 | 100 | 25 | 1 |
| 522 | 23 | 90 | 27 | 25 | 100 | 30 |
| 523 | 0 | 27 | 90 | 1 | 30 | 100 |
| 531 | 0 | 10 | 50 | 0 | 9 | 45 |

Due to the physical properties of the ultrasound propagation (changes in the Point Spread Function in different positions of the display), the matching score between 511 and 522 will not be as high as 511 against 512. However, it may be expected to be in close vicinity, which may be utilized when forming the matching sequence, i.e. when ranking the sub-templates.

In some embodiments, the matching scores between feature points 531 and any other sub-template may indicate how high the probability is that a comparison between the sub-template in question and feature points 531 will be successful.

In case of Fig. 5 there may be e.g. a 50 % chance that comparing the feature points 531 with sub-template 513 will result in a successful authentication.

In Fig. 5 it is easy to see that if sub-template 513 exists it is probable that it will yield a match against feature points 531 since the matching score between 531 and 513 is 50.

However, in case sub-template 513 doesn't exist and the matching threshold may e.g. be set to 30. Then in some embodiments, when all of the sub-templates of Zone A have been matched against the feature points 531 and no successful authorization has been achieved or it is determined that none of the sub-templates for zone A exceeds the matching threshold, leading to that no match for zone A is made, the overlap scheme may dictate that matching should be performed to the sub-templates in Zone B that has the highest matching score in relation to sub-template 512 as this sub-template gave the highest score against feature points 531 in zone A (i.e. 10).

In this particular example, matching would first be performed between the sub-template 522 and the feature points 531 since the sub-template 522 has a matching score of 90 compared to the sub-template 512. However, in relation to the extracted feature points 531, the sub-template 522 yields a matching score of 9 which does not exceed the matching threshold, and hence authorization will be unsuccessful. Hence, matching is then made against 523, which has the next highest score in relation to sub-template 512 (a score of 27) and which yields a matching score in relation to the extracted feature point of 45, which does exceed the threshold.

In the example above, matching against sub-template 521 is avoided before matching with sub-template 523 since sub-template 521 has a matching score of 23 compared to sub-template 512. Hence one less iteration is needed. If there are many zones with several sub-templates in each zone, this procedure could give an advantage since verification time is decreased together with decreased computer processing.

In some embodiments, the overlap matrix may also be combined or used in combination with the popularity score explained in conjunction with Fig. 3.

Hence in some embodiments, the method 100 described in Fig. 1 may further comprise determining whether a respective one or more sub-templates associated with the first position overlaps with a respective one or more sub-templates associated with the one or more positions of the display.

The method 100 may also comprise determining whether a respective one or more sub-templates associated with the first position overlaps with a respective one or more sub-templates associated with the one or more positions of the display and then determining a matching score between the respective one or more sub-templates

associated with the first position and the respective one or more sub-templates associated with the one or more positions of the display.

The method 100 may also comprise forming an overlap matrix (as described in conjunction with Fig. 5), wherein the overlap matrix comprises a mapping over each sub-template's respective matching score.

In some embodiments, when feature points has been extracted from a fingerprint, the extracted feature points may also be added (e.g. as a verification template) to the overlap matrix and be assigned a matching score in relation to the stored sub-templates.

In some embodiments, the method may additionally or alternatively comprise determining whether a respective one or more sub-templates associated with the first position overlaps with a respective one or more other sub-templates associated with the first positions of the display and determining a matching score indicative of the overlap between the respective one or more sub-templates associated with the first position and the respective one or more other sub-templates associated with the first position of the display. The method may then comprise forming an overlap matrix, wherein the overlap matrix comprises a mapping over each sub-template's respective matching score associated with the first position.

Hence an overlap matrix may in some embodiments be formed which comprises all sub-templates for all positions of the display. In some embodiments, an overlap matrix may comprise all sub-templated associated with a certain position.

In some embodiments, the overlap matrix may comprise all sub-templates associated with a subset of the positions of the display.

The overlap matrix may also be used when verifying an acquired fingerprint as described in Fig. 5.

Hence the method 200 described in conjunction with Fig. 2 may also comprise an overlap matrix comprising a mapping over each of the sub-templates, wherein each of the sub-templates are associated with a matching score indicative of an overlap between each of the sub-templates in relation to each other.

When e.g. it is determined that the extracted at least one feature point of the acquired at least one fingerprint does not match the one or more feature points associated with the stored first sub-template associated with the first position, the method may comprise determining whether the overlap matrix comprises at least one

sub-template associated with a matching score which exceeds a matching threshold in relation to the stored first sub-template.

When it is determined that the overlap matrix comprises at least one sub-template associated with a matching score which exceeds a matching threshold in relation to the stored first sub-template the method may comprise comparing the extracted at least one feature point to one or more feature points associated with the at least one sub-template associated with a matching score which exceeds a matching threshold in relation to the stored first sub-template.

Based on the comparison, the method 200 may comprise determining whether the extracted at least one feature point of the acquired at least one fingerprint matches one or more feature points associated with the at least one sub-template associated with a matching score which exceeds a matching threshold in relation to the stored first sub-template.

In some embodiments, the matching threshold may be in a range between 0-100 and may depend on how parameters such as system performance and system limitation.

If few computing resources are available the matching threshold should preferably be set relatively high whereas if no significant care has to be taken in terms of conserving computing powers, the matching threshold should preferably bet set relatively low.

A high matching threshold will filter out several iterations, whereas a low threshold will allow more iterations in order to find a match.

In some embodiments, a high threshold may e.g. be in the ranges of 50-100 or 70-100 or 90-100.

In some embodiments, a low threshold may e.g. be in the ranges of 0-49, or 0-30, or 0-10 or similar.

The embodiments as described in conjunction with the overlap matrix may also be combined with the method 300 described in conjunction with Fig. 3.

The methods described herein will typically be carried out by a device comprising some sort of display, where the device may comprise some sort of arrangement or system for enabling the methods.

Fig. 6 illustrates such an example arrangement 600 according to some embodiments.

The arrangement 600 may be configured to enroll and verify fingerprints of a user, and configured to be associated with (e.g. may be connectable to) a display wherein the display may comprise or be associated with ultrasonic sensors configured to detect fingerprints on the surface of the display.

In some embodiments, one or more positions on the display are defined, each position being associated with a respective set of coordinates, wherein the respective set of coordinates defines where on the display the one or more positions are located.

In some embodiments, the arrangement comprises a controller (CNTR) 620 configured to cause association of at least one of the one or more positions with at least one sub-template associated with one or more feature points associated with a fingerprint of the user.

In some embodiments, the arrangement 600 may be configured to carry out or cause execution of one or more of the method steps described for either of the methods described in conjunction with any of the previous figures.

In some embodiments, the arrangement 600 may additionally comprise a display. In some embodiments, the arrangement 600 may be comprised in an electronic device. The electronic device may comprise a display. In some embodiments, the electronic device may be a mobile phone, a smart card, a computer, a digital display, a surf pad, a smart-board, a display in a vault or safe etc.

In some embodiments, the arrangement may further comprise a sensor (SENS) 610 comprising sensing elements or sensing circuitry configured to detect touches.

In some embodiments the sensor 610 may be operatively connected to the controller 620 and/or the display or be comprised within the controller 620 and/or the display.

In some embodiments, the controller 620 may further comprise or be associated with a detector (DETECT) 621 comprising detecting circuitry, an extractor (EXT) 622 comprising feature extracting circuitry and a sub-template generator (SUB) 623 comprising circuitry for generating sub-templates.

In some embodiments, the controller 620 is further configured to cause an enrollment process of the user by causing prompting of the user to touch a first position associated with a first set of coordinates of the display one or more times.

The controller may also be configured to cause detection of at least one touch occasion in the first position of the display wherein each touch occasion results in a respective fingerprint, e.g. by causing the sensor 610 to detect the touches.

In some embodiments, the controller 620 if further configured to cause extraction of a number of feature points from each respective fingerprint, e.g. by causing the extractor 622.

The controller 620 may also be configured to cause formation of one or more sub-templates comprising the number of feature points associated with the respective fingerprint and associating the one or more sub-templates with the first position by storing information pertaining to the first set of coordinates in the sub-template. The controller 620 may e.g. be configured to cause the sub-template generator 623 to request the extracted feature points from the extractor 622 and form one or more sub-templates based on the feature points.

The controller 620 may also be configured to cause storing the one or more sub-templates associated with the first position, wherein the number of feature points associated with the one or more stored sub-templates is associated with the enrolled user. E.g. by causing the sub-template generator 623 to associate the sub-templates with the position in which the detected touches occurred, and store the formed sub-templates.

In some embodiments, the controller 620 is further configured to cause repetition of the steps of prompting, obtaining, forming, and storing for each of the one or more positions of the display.

In some embodiments, the controller 620 is further configured to cause determination of whether a respective one or more sub-templates associated with the first position overlaps with a respective one or more sub-templates associated with the one or more positions of the display. The controller 620 may e.g. be configured to cause the sub-template generator 623 possibly in cooperation with the extractor 622 to determine whether one or more of the sub-templates associated with the first position and the one or more positions of the display overlaps.

In some embodiments, the controller 620 may be configured to cause determination of a matching score indicative of the overlap between the respective one or more sub-templates associated with the first position and the respective one or more sub-templates associated with the one or more positions of the display and cause formation of an overlap matrix, wherein the overlap matrix comprises a mapping over each sub-template's respective matching score (compare with Fig. 5).

In some embodiments, the controller 620 is further configured to cause determination of whether a respective one or more sub-templates associated with the

first position overlaps with a respective one or more other sub-templates associated with the first positions of the display.

The controller 620 may e.g. be configured to cause the formation of an overlap matrix comprising all sub-templates associated with the first position.

In some embodiments, the controller 620 may be further configured to cause determination of a matching score indicative of the overlap between the respective one or more sub-templates associated with the first position and the respective one or more other sub-templates associated with the first position of the display and cause formation of an overlap matrix, wherein the overlap matrix comprises a mapping over each sub-template's respective matching score associated with the first position (compare with Fig. 5).

In some embodiments, the controller 620 may be further configured to cause arranging of the one or more positions on the display into one or more groups. In some embodiments, the one or more groups may define at least one zone associated with a group of sub-templates. The sub-templates of the group of sub-templates may be associated with the one or more positions forming the at least one zone, and the at least one zone covers at least a part of the display (compare e.g. with Fig. 4).

In addition (or as an alternative) to causing the enrollment process (e.g. the enrollment process described in the method 100 of Fig. 1) the controller 620 may also be configured to cause a verification process of a fingerprint associated with a second user detected on the display in order to determine that the second user is the enrolled user. The controller 620 may e.g. be configured to cause detection of a touch occasion in a first position of the one or more positions of the display, e.g. by causing the sensor 610 to detect the touch (compare with the method 100 and 200).

The controller 620 may also be configured to cause acquisition of at least one fingerprint associated with the detected touch occasion and cause extraction (e.g. by means of causing the extractor 622) of at least one feature point from the acquired at least one fingerprint.

In some embodiments, the controller 620 may be configured to cause comparison of the extracted at least one feature point of the acquired at least one fingerprint to one or more feature points associated with a stored first sub-template associated with the first position.

The controller 620 may then be configured to, based on the comparison, to cause determination of whether the extracted at least one feature point of the acquired

at least one fingerprint matches the one or more feature points associated with the stored first sub-template associated with the first position.

The controller 620 may achieve this e.g. by causing the extractor 622 to cooperate with the sub-template generator 623.

When it is determined that the extracted at least one feature point of the acquired at least one fingerprint matches the one or more feature points associated with the stored first sub-template, the controller 620 may be configured to cause determination of that the second user is the enrolled user and verification of an identity of the second user and authorization of the second user.

E.g. if a match is found it is an indication that the user requesting to be identified has already enrolled a fingerprint and hence is an authorized user.

When it is determined that the extracted at least one feature point of the acquired at least one fingerprint does not match the one or more feature points associated with the stored first sub-template associated with the first position, it may be an indication that the user is not the enrolled user, or that the acquired fingerprint is of different quality than what is represented by the sub-template. Hence when no match is made between the extracted features and the stored first sub-template associated with the first position, the controller 620 may be further configured to cause comparison of the extracted at least one feature point of the acquired at least one fingerprint to one or more feature points associated with a stored second sub-template associated with the first position.

It may e.g. be that a second sub-template associated with the first position represents a more accurate representation of the stored fingerprint than the first sub-template with regards to the acquired fingerprint based on e.g. position. If the display has been divided into zones, it may e.g. be that the position of the sub-template is slightly different than the position of where the fingerprint was acquired. Or, it may be that one position has many sub-templates with equal coordinates but that the finger touched the display at different angles or with different pressure when enrolling.

The controller 620 may hence be further configured to cause determination of, based on the comparison, whether the extracted at least one feature point of the acquired at least one fingerprint matches one or more feature points associated with the stored second sub-template associated with the first position.

When it is determined that the extracted at least one feature point of the acquired at least one fingerprint matches the one or more feature points associated with

the stored second sub-template associated with the first position, the controller 620 may be configured to cause determination of that the second user is the enrolled user and cause verification of the identity of the second user and authorization of the second user (compare with the method 200).

In some embodiments, when it is determined that the extracted at least one feature point of the acquired at least one fingerprint does not match the one or more feature points associated with the at least one stored second sub-template associated with the first location, the controller 620 may be configured to cause comparison of the extracted at least one feature point of the acquired at least one fingerprint to one or more feature points associated with at least one stored sub-template associated with at least one second position.

Hence, if no match is found when comparing the second sub-template associated with the first position, the controller 620 may be configured to cause comparison to sub-templates stored for a second position of the display (compare with the method 200).

Hence, the controller 620 may further be configured to cause determination of, based on the comparison, whether the extracted at least one feature point of the acquired at least one fingerprint matches one or more feature points associated with the at least one stored sub-template associated with the at least one second position.

In some embodiments, when it is determined that the extracted at least one feature point of the acquired at least one fingerprint does not match one or more feature points associated with the at least one stored sub-template associated with the at least one second position the controller 620 may be configured to cause comparison of the extracted at least one feature point of the acquired at least one fingerprint to each of the one or more feature points associated with each of the stored sub-templates associated with each of the one or more positions of the display until a match is found, or until each of the feature points associated with each of the stored sub-templates associated with each of the one or more positions of the display has been compared to the extracted at least one feature point of the acquired at least one fingerprint.

Hence the controller 620 may cause iteration through all of the stored sub-templates associated with each of the positions of the display until a match is found or until there are no more stored sub-templates.

In some embodiments, the controller 620 may be configured to iterate through only a sub-set of the positions and their associated sub-templates.

When it is determined that no match is found after comparing the extracted at least one feature point of the acquired at least one fingerprint to each of the one or more feature points associated with each of the stored sub-templates associated with each of the one or more positions of the display, the controller 620 may be configured to cause determination of that the second user is not the enrolled user and further cause denial of authorization of the second user (compare with the method 200).

In some embodiments, the controller 620 may further be configured to cause association of each stored sub-template associated with each of the one or more positions of the display with a popularity score, wherein a sub-template associated with a high popularity score is indicative of that the sub-template is used more often for successful authorization of the enrolled user than a sub-template associated with a low popularity score (compare with the method 300).

In some embodiments, the controller 620 may be configured to use a stored sub-template associated with the first position in which the touch occasion occurred, which sub-template is associated with a highest popularity score among the popularity scores associated with each of the at least one stored sub-templates associated with the first position first in order to determine if the second user is the enrolled user. E.g. by the controller being configured to cause comparing of the at least one extracted feature point of the acquired fingerprint to the one or more feature points associated with the stored sub-template associated with the highest popularity score associated with the first position (compare with the method 300).

In some embodiments, when it is determined that the second user is not the enrolled user when comparing the one or more feature points associated with the stored sub-template associated with the highest popularity score associated with the first position to the extracted at least one feature point of the acquired fingerprint, the controller 620 may be further configured to cause comparison of the at least one feature point to each of the stored sub-templates associated with the highest popularity score associated with each of the one or more positions of the display (compare with the method 300 described in conjunction with Fig. 3).

In some embodiments, the controller 620 may be further configured to use a stored sub-template associated with a highest popularity score among the popularity scores associated with each of the stored sub-templates associated with each of the one or more positions of the display first in order to determine if the second user is the enrolled user.

In some embodiments, when it is determined that the extracted at least one feature point of the acquired at least one fingerprint does not match the one or more feature points associated with the stored first sub-template associated with the first position (e.g. when performing the method 200), the controller 620 may be further configured to cause determination of whether the overlap matrix comprises at least one sub-template associated with a matching score which exceeds a matching threshold in relation to the stored first sub-template.

When it is determined that the overlap matrix comprises at least one sub-template associated with the matching score which exceeds a matching threshold in relation to the stored first sub-template the controller 620 may be configured to cause comparison of the extracted at least one feature point to one or more feature points associated with the at least one sub-template associated with the matching score which exceeds a matching threshold in relation to the stored first sub-template.

The controller 620 may also be configured to cause determination based on the comparison of whether the extracted at least one feature point of the acquired at least one fingerprint matches one or more feature points associated with the at least sub-template associated with the matching score which exceeds a matching threshold in relation to the stored first sub-template (compare with Fig. 5).

In some embodiments, the controller 620 may be configured to additionally or alternatively utilize an overlap matrix which covers only a single position, or a subset of positions instead of each of the positions of the display when determining which sub-template to use for matching based on the matching score (compare with overlap matrix described for enrolling a fingerprint in conjunction with fig. 5).

Fig. 7 illustrates a computer program product comprising a non-transitory computer readable medium 700, wherein the non-transitory computer readable medium 700 has stored there on a computer program comprising program instructions. The computer program is configured to be loadable into a data-processing unit 710, comprising a processor (PROC) 730 and a memory (MEM) 720 associated with or integral to the data-processing unit. When loaded into the data-processing unit 710, the computer program is configured to be stored in the memory 720, wherein the computer program, when loaded into and run by the processor 730 is configured to cause the processor to execute method steps according to any of the methods described in conjunction with the figures 1-5.

The embodiments described herein enable an enrollment and verification process of biometric data which is fast and robust.

Furthermore, by means of the methods and arrangement described herein ensures that the enrollment and verification process takes into consideration technical features of the ultrasonic sensor technology for acquiring fingerprints.

By storing sub-templates comprising feature points from one or more fingerprints and associating the sub-templates to the positions of the display in which the fingerprints were acquired it is taken into consideration that the extracted feature points pertaining to the same finger may retain different characteristics based on where on the display they were acquired due to the ultrasonic sensors.

Hence, the enrollment and verification process is not affected and will still be reliable for in-display acquisition.

Furthermore, the methods and arrangement enables collecting and storing a relatively large amount of sub-templates while still keeping the complexity and processing demands of the verification process low leading to that the verification process will be quick and simple.

The described embodiments and their equivalents may be realized in software or hardware or a combination thereof. They may be performed by general-purpose circuits associated with or integral to a communication device, such as digital signal processors (DSP), central processing units (CPU), co-processor units, field-programmable gate arrays (FPGA) or other programmable hardware, or by specialized circuits such as for example application-specific integrated circuits (ASIC). All such forms are contemplated to be within the scope of this disclosure.

Embodiments may appear within an electronic apparatus (such as a wireless communication device) comprising circuitry/logic or performing methods according to any of the embodiments. The electronic apparatus may, for example, be a portable or handheld mobile radio communication equipment, a mobile radio terminal, a mobile telephone, a pager, a communicator, an electronic organizer, a smartphone, a computer, a notebook, a USB-stick, a plug-in card, a smart card, a digital display an embedded drive, or a mobile gaming device.

According to some embodiments, a non-transitory computer program product comprises a computer readable medium such as, for example, a diskette or a CD-ROM.

Reference has been made herein to various embodiments. However, a person skilled in the art would recognize numerous variations to the described embodiments

that would still fall within the scope of the claims. For example, the method embodiments described herein describes example methods through method steps being performed in a certain order. However, it is recognized that these sequences of events may take place in another order without departing from the scope of the claims. Furthermore, some method steps may be performed in parallel even though they have been described as being performed in sequence.

In the same manner, it should be noted that in the description of embodiments, the partition of functional blocks into particular units is by no means limiting. Contrarily, these partitions are merely examples. Functional blocks described herein as one unit may be split into two or more units. In the same manner, functional blocks that are described herein as being implemented as two or more units may be implemented as a single unit without departing from the scope of the claims.

Hence, it should be understood that the details of the described embodiments are merely for illustrative purpose and by no means limiting. Instead, all variations that fall within the range of the claims are intended to be embraced therein.

# CLAIMS

1. A method for enrolling a fingerprint associated with a user and detected on a display in order to enroll the user, wherein the display comprises ultrasonic sensors configured to detect fingerprints on the surface of the display, wherein one or more positions on the display are defined, each position associated with a respective set of coordinates, wherein the respective set of coordinates defines where on the display the one or more positions are located, and wherein the method comprises:

- prompting the user to touch a first position on the display associated with a first set of coordinates one or more times;

- detecting at least one touch occasion in the first position of the display wherein each touch occasion results in a respective fingerprint;

- extracting a number of feature points from each respective fingerprint;

- forming one or more sub-templates comprising the number of feature points extracted from the respective fingerprint and associating the one or more sub-templates with the first position by storing information pertaining to the first set of coordinates in the sub-template; and

- storing the one or more sub-templates associated with the first position, wherein the number of feature points associated with the one or more stored sub-templates is associated with the enrolled user.

2. The method according to claim 1, further comprising repeating the steps of prompting, obtaining, forming and storing for each of the one or more positions of the display.

3. The method according to any of the previous claims, further comprising:

- determining whether a respective one or more sub-templates associated with the first position overlaps with a respective one or more sub-templates associated with the one or more positions of the display;

- determining a matching score between the respective one or more sub-templates associated with the first position and the respective one or more sub-templates associated with the one or more positions of the display; and

- forming an overlap matrix, wherein the overlap matrix comprises a mapping over each sub-template's respective matching score; or

- determining whether a respective one or more sub-templates associated with the first position overlaps with a respective one or more other sub-templates associated with the first positions of the display;

- determining a matching score between the respective one or more sub-templates associated with the first position and the respective one or more other sub-templates associated with the first position of the display; and

- forming an overlap matrix, wherein the overlap matrix comprises a mapping over each sub-template's respective matching score associated with the first position.

4. The method according to any of the previous claims, wherein the one or more positions of the display, are arranged in one or more groups, wherein the one or more groups defines at least one zone associated with a group of sub-templates, wherein the sub-template of the group of sub-templates are associated with the one or more positions forming the at least one zone, and wherein the at least one zone covers at least a part of the display.

5. A method for verifying a fingerprint associated with a user and detected on a display in order to determine whether the user is an enrolled user, wherein the display comprises ultrasonic sensors configured to detect fingerprints on the surface of the display, wherein one or more positions on the display are defined, each position associated with a set of coordinates, wherein the respective set of coordinates defines where on the display the one or more positions are located, wherein each of the one or more positions of the display is associated with one or more stored sub-templates comprising a number of feature points associated with a fingerprint associated with the enrolled user, and wherein the method comprises:

- detecting a touch occasion in a first position of the one or more positions on the display;

- acquiring at least one fingerprint associated with the detected touch occasion;

- extracting at least one feature point from the acquired at least one fingerprint;

- comparing the extracted at least one feature point of the acquired at least one fingerprint to one or more feature points associated with a stored first sub-template associated with the first position:

- determining, based on the comparison, whether the extracted at least one feature point of the acquired at least one fingerprint matches the one or more feature

points associated with the stored first sub-template associated with the first position; and

- when it is determined that the extracted at least one feature point of the acquired at least one fingerprint matches the one or more feature points associated with the stored first sub-template:

- determining that the user is the enrolled user; and

- verifying an identity of the user and authorizing the user.

6. The method according to claim 5, further comprising, when it is determined that the extracted at least one feature point of the acquired at least one fingerprint does not match the one or more feature points associated with the stored first sub-template associated with the first position:

- comparing the extracted at least one feature point of the acquired at least one fingerprint to one or more feature points associated with a stored second sub-template associated with the first position;

- determining based on the comparison whether the extracted at least one feature point of the acquired at least one fingerprint matches one or more feature points associated with the stored second sub-template associated with the first position; and

- when it is determined that the extracted at least one feature point of the acquired at least one fingerprint matches the one or more feature points associated with the stored second sub-template associated with the first position:

- determining that the user is the enrolled user; and

- verifying the identity of the user and authorizing the user.

7. The method according to claim 6, further comprising, when it is determined that the extracted at least one feature point of the acquired at least one fingerprint does not match the one or more feature points associated with the at least one stored second sub-template associated with the first position:

- comparing the extracted at least one feature point of the acquired at least one fingerprint to one or more feature points associated with at least one stored sub-template associated with at least one second position;

- determining based on the comparison whether the extracted at least one feature point of the acquired at least one fingerprint matches one or more feature points

associated with the at least one stored sub-template associated with the at least one second position.

8. The method according to claim 7, further comprising, when it is determined that the extracted at least one feature point of the acquired at least one fingerprint does not match one or more feature points associated with the at least one stored sub-template associated with the at least one second position:

- comparing the extracted at least one feature point of the acquired at least one fingerprint to each of the one or more feature points associated with each of the stored sub-templates associated with each of the one or more positions of the display until a match is found, or until each of the feature points associated with each of the stored sub-templates associated with each of the one or more positions of the display has been compared to the extracted at least one feature point of the acquired at least one fingerprint.

9. The method according to claim 8, further comprising, when it is determined that no match is found after comparing the extracted at least one feature point of the acquired at least one fingerprint to each of the one or more feature points associated with each of the stored sub-templates associated with each of the one or more positions of the display:

- determining that the user is not the enrolled user; and
- denying authorization to the user.

10. The method according to any of the claims 5-9, wherein each stored sub-template associated with each of the one or more positions of the display is associated with a popularity score, wherein a sub-template having a high popularity score is indicative of that the sub-template is used more often for successful authorization of the user than a sub-template having a low popularity score.

11. The method according to claim 10, wherein a stored sub-template associated with the first position in which the touch occasion occurred associated with a highest popularity score among the popularity scores associated with each of the at least one stored sub-templates associated with the first position is used first in order to determine if the user is the enrolled user by comparing the at least one extracted feature

point of the acquired fingerprint to the one or more feature points associated with the stored sub-template associated with the highest popularity score associated with the first position.

12. The method according to claim 11, wherein if it is determined that the user is not the enrolled user when comparing the one or more feature points associated with the stored sub-template associated with the highest popularity score associated with the first position to the extracted at least one feature point of the acquired at least one fingerprint, the method further comprises comparing the at least one feature point to each of the stored sub-templates associated with the highest popularity score associated with each of the one or more positions of the display.

13. The method according to claim 12, wherein a stored sub-template associated with a highest popularity score among the popularity scores associated with each of the stored sub-templates associated with each of one or more positions of the display is used first in order to determine if the user is the enrolled user.

14. The method according to any of the claims 5-13 further comprising an overlap matrix comprising a mapping over each of the stored sub-templates, wherein each of the stored sub-templates are associated with a matching score between each of the stored sub-templates in relation to each other, and wherein the method further comprises:

- adding the extracted at least one feature point to the overlap matrix and determining a matching score of the extracted at least one feature point in relation to each of the stored sub-templates in the overlap matrix;

- comparing the extracted at least one feature point to a sub-template associated with the first position having a highest matching score in relation to the extracted at least one feature point, wherein when it is determined that the extracted at least one feature point of the acquired at least one fingerprint does not match the one or more feature points associated with the sub-template associated with the first position having the highest matching score in relation to the extracted at least one feature point, the method comprises:

- determining whether the overlap matrix comprises at least one sub-template associated with a matching score which exceeds a matching threshold in relation to the

sub-template associated with the first position having the highest matching score in relation to the extracted at least one feature point, wherein when it is determined that the overlap matrix comprises at least one sub-template associated with a matching score which exceeds a matching threshold in relation to the sub-template associated with the first position having the highest matching score in relation to the extracted at least one feature point, the method comprises :

- comparing the extracted at least one feature point to one or more feature points associated with the at least one sub-template associated with the matching score which exceeds the matching threshold in relation to the sub-template associated with the first position having the highest matching score in relation to the extracted at least one feature point; and

- determining based on the comparison whether the extracted at least one feature point of the acquired at least one fingerprint matches one or more feature points associated with the at least one sub-template associated with the matching score which exceeds the matching threshold in relation to sub-template associated with the first position having the highest matching score in relation to the extracted at least one feature point.

15. An arrangement configured to enroll and verify fingerprints of a user, and configured to be associated with a display wherein the display comprises ultrasonic sensors configured to detect fingerprints on the surface of the display, wherein one or more positions on the display are defined, each position associated with a respective set of coordinates, wherein the respective set of coordinates defines where on the display the one or more positions are located, and wherein the arrangement comprises a controller configured to cause association of at least one of the one or more positions with at least one sub-template associated with one or more feature points associated with a fingerprint of the user.

16. The arrangement according to claim 15, wherein the controller is further configured to cause an enrollment process of the user by causing:

- prompting of the user to touch a first position associated with a first set of coordinates of the display one or more times;

- detection of at least one touch occasion in the first position of the display wherein each touch occasion results in a respective fingerprint;

- extraction of a number of feature points from each respective fingerprint;

- formation of one or more sub-templates comprising the number of feature points associated with the respective fingerprint and associating the one or more sub-templates with the first position by storing information pertaining to the first set of coordinates in the sub-template; and

- storing the one or more sub-templates associated with the first position, wherein the number of feature points associated with the one or more stored sub-templates is associated with the enrolled user.

17. The arrangement according to claim 16, wherein the controller is further configured to cause repetition of the steps of prompting, obtaining, forming, and storing for each of the one or more positions of the display.

18. The arrangement according to any of the claims 15-16, wherein the controller is further configured to cause:

- determination of whether a respective one or more sub-templates associated with the first position overlaps with a respective one or more sub-templates associated with the one or more positions of the display;

- determination of a matching score between the respective one or more sub-templates associated with the first position and the respective one or more sub-templates associated with the one or more positions of the display; and

- formation of an overlap matrix, wherein the overlap matrix comprises a mapping over each sub-template's respective matching score; or to cause

- determination of whether a respective one or more sub-templates associated with the first position overlaps with a respective one or more other sub-templates associated with the first positions of the display;

- determination of a matching score between the respective one or more sub-templates associated with the first position and the respective one or more other sub-templates associated with the first position of the display; and

- formation of an overlap matrix, wherein the overlap matrix comprises a mapping over each sub-template's respective matching score associated with the first position.

19. The arrangement according to any of the claims 15-18, wherein the controller is further configured to cause arranging of the one or more positions on the display into one or more groups, wherein the one or more groups defines at least one zone associated with a group of sub-templates, wherein the sub-templates of the group of sub-templates are associated with the one or more positions forming the at least one zone, and wherein the at least one zone covers at least a part of the display.

20. The arrangement according to any of the claims 15-19, wherein the controller is further configured to cause a verification process of a fingerprint associated with a second user detected on the display in order to determine that the second user is the enrolled user, by causing:

- detection of a touch occasion in a first position of the one or more positions of the display;

- acquisition of at least one fingerprint associated with the detected touch occasion;

- extraction of at least one feature point from the acquired at least one fingerprint;

- comparison of the extracted at least one feature point of the acquired at least one fingerprint to one or more feature points associated with a stored first sub-template associated with the first position; wherein the controller is configured to, based on the comparison, cause:

- determination of whether the extracted at least one feature point of the acquired at least one fingerprint matches the one or more feature points associated with the stored first sub-template associated with the first position; wherein when it is determined that the extracted at least one feature point of the acquired at least one fingerprint matches the one or more feature points associated with the stored first sub-template, the controller is configured to cause:

- determination of that the second user is the enrolled user; and

- verification of an identity of the second user and authorization of the second user.

21. The arrangement according to claim 20, wherein the controller is further configured to cause, when it is determined that the extracted at least one feature point of

the acquired at least one fingerprint does not match the one or more feature points associated with the stored first sub-template associated with the first position:

- comparison of the extracted at least one feature point of the acquired at least one fingerprint to one or more feature points associated with a stored second sub-template associated with the first position;

- determination of, based on the comparison, whether the extracted at least one feature point of the acquired at least one fingerprint matches one or more feature points associated with the stored second sub-template associated with the first position; and

wherein when it is determined that the extracted at least one feature point of the acquired at least one fingerprint matches the one or more feature points associated with the stored second sub-template associated with the first position:

- determination of that the second user is the enrolled user; and

- verification of the identity of the second user and authorization of the second user.

22. The arrangement according to claim 20, wherein the controller is further configured to cause, when it is determined that the extracted at least one feature point of the acquired at least one fingerprint does not match the one or more feature points associated with the at least one stored second sub-template associated with the first location:

- comparison of the extracted at least one feature point of the acquired at least one fingerprint to one or more feature points associated with at least one stored sub-template associated with at least one second position; and

- determination of, based on the comparison, whether the extracted at least one feature point of the acquired at least one fingerprint matches one or more feature points associated with the at least one stored sub-template associated with the at least one second position.

23. The arrangement according to claim 22, wherein the controller is further configured to cause, when it is determined that the extracted at least one feature point of the acquired at least one fingerprint does not match one or more feature points associated with the at least one stored sub-template associated with the at least one second position:

- comparison of the extracted at least one feature point of the acquired at least one fingerprint to each of the one or more feature points associated with each of the stored sub-templates associated with each of the one or more positions of the display until a match is found, or until each of the feature points associated with each of the stored sub-templates associated with each of the one or more positions of the display has been compared to the extracted at least one feature point of the acquired at least one fingerprint.

24. The arrangement according to claim 23, wherein the controller is further configured to cause, when it is determined that no match is found after comparing the extracted at least one feature point of the acquired at least one fingerprint to each of the one or more feature points associated with each of the stored sub-templates associated with each of the one or more positions of the display:

- determination of that the second user is not the enrolled user; and
- denial of authorization of the second user.

25. The arrangement according to any of the claims 20-24, wherein the controller is further configured to cause association of each stored sub-template associated with each of the one or more positions of the display with a popularity score, wherein a sub-template associated with a high popularity score is indicative of that the sub-template is used more often for successful authorization of the enrolled user than a sub-template associated with a low popularity score.

26. The arrangement according to claim 24, wherein a stored sub-template associated with the first position in which the touch occasion occurred associated with a highest popularity score among the popularity scores associated with each of the at least one stored sub-templates associated with the first position is used first in order to determine if the second user is the enrolled user by comparing the at least one extracted feature point of the acquired fingerprint to the one or more feature points associated with the stored sub-template associated with the highest popularity score associated with the first position.

27. The arrangement according to claim 26, wherein if it is determined that the second user is not the enrolled user when comparing the one or more feature points

associated with the stored sub-template associated with the highest popularity score associated with the first position to the extracted at least one feature point of the acquired fingerprint, the controller is further configured to cause comparison of the at least one feature point to each of the stored sub-templates associated with the highest popularity score associated with each of the one or more positions of the display.

28. The arrangement according to claim 27, wherein a stored sub-template associated with a highest popularity score among the popularity scores associated with each of the stored sub-templates associated with each of one or more positions of the display is used first in order to determine if the second user is the enrolled user.

29. The arrangement according to any of the claims 17-28 wherein the controller is further configured to cause:

- addition of the extracted at least one feature point to the overlap matrix and determining a matching score of the extracted at least one feature point in relation to each of the stored sub-templates in the overlap matrix;

- comparison of the extracted at least one feature point to a sub-template associated with the first position having a highest matching score in relation to the extracted at least one feature point, wherein when it is determined that the extracted at least one feature point of the acquired at least one fingerprint does not match the one or more feature points associated with the sub-template associated with the first position having the highest matching score in relation to the extracted at least one feature point, the controller is further configured to cause:

- determination of whether the overlap matrix comprises at least one sub-template associated with a matching score which exceeds a matching threshold in relation to the sub-template associated with the first position having the highest matching score in relation to the extracted at least one feature point, wherein when it is determined that the overlap matrix comprises at least one sub-template associated with a matching score which exceeds a matching threshold in relation to the sub-template associated with the first position having the highest matching score in relation to the extracted at least one feature point, the controller is configured to cause

- comparison of the extracted at least one feature point to one or more feature points associated with the at least one sub-template associated with the matching score which exceeds the matching threshold in relation to the sub-template point associated

with the first position having the highest matching score in relation to the extracted at least one feature; and

- determination based on the comparison whether the extracted at least one feature point of the acquired at least one fingerprint matches one or more feature points associated with the at least one sub-template associated with the matching score which exceeds the matching threshold in relation to the sub-template associated with the first position having the highest matching score in relation to the extracted at least one feature point.

30. An electronic device comprising the arrangement according to any of the claims 15-29.

31. A computer program product comprising a non-transitory computer readable medium, wherein the computer readable medium has stored there on a computer program comprising program instructions, wherein the computer program is configured to be loadable into a data-processing unit, comprising a processor and a memory associated with or integral to the data-processing unit, wherein when loaded into the data-processing unit, the computer program is configured to be stored in the memory, and wherein the computer program, when loaded into and run by the processor is configured to cause the processor to execute method steps according to any of the claims 1-14.

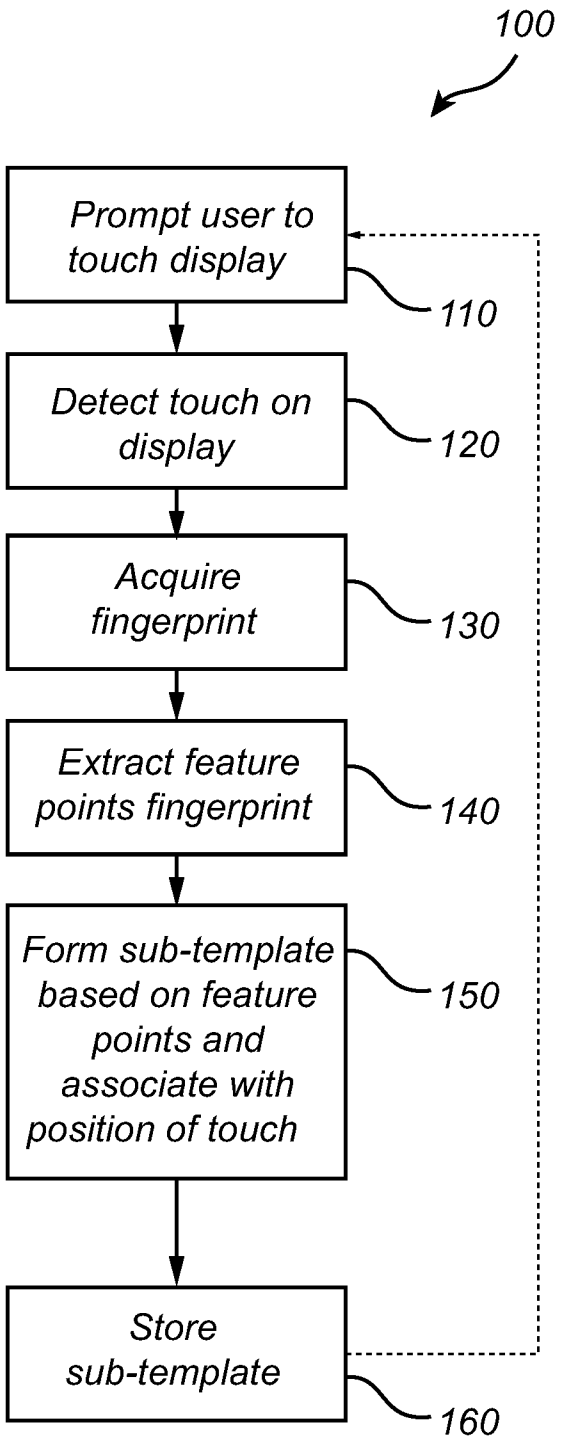
100
Prompt user to touch display
110
Detect touch on display
120
Acquire fingerprint
130
Extract feature points fingerprint
140
Form sub-template based on feature points and associate with position of touch
150
Store sub-template
160

Fig. 1

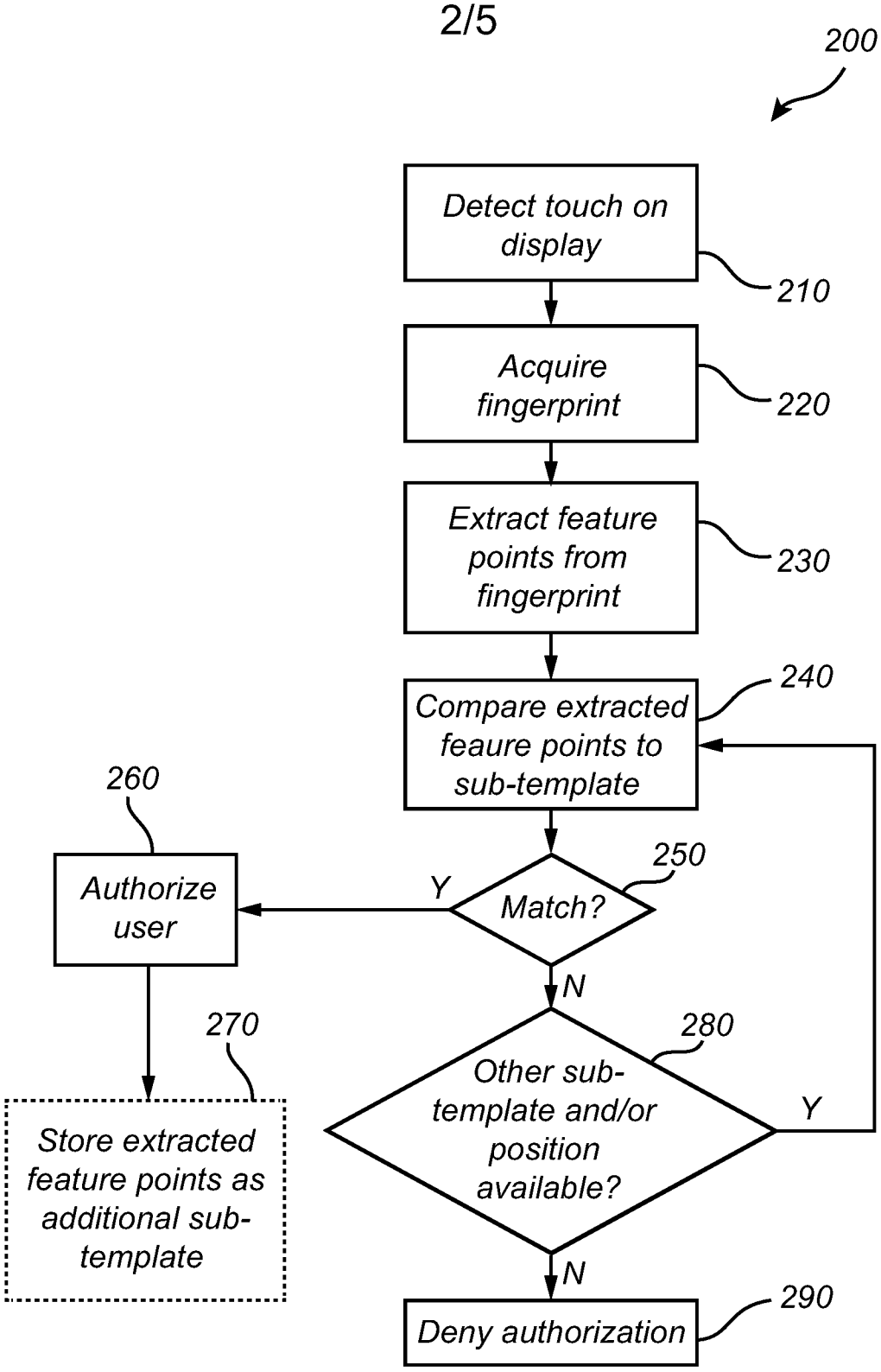
200
Detect touch on display
210
Acquire fingerprint
220
Extract feature points from fingerprint
230
Compare extracted feaure points to sub-template
240
Match?
250
Y
Authorize user
260
N
Other sub-template and/or position available?
280
Y
N
Store extracted feature points as additional sub-template
270
Deny authorization
290

Fig. 2

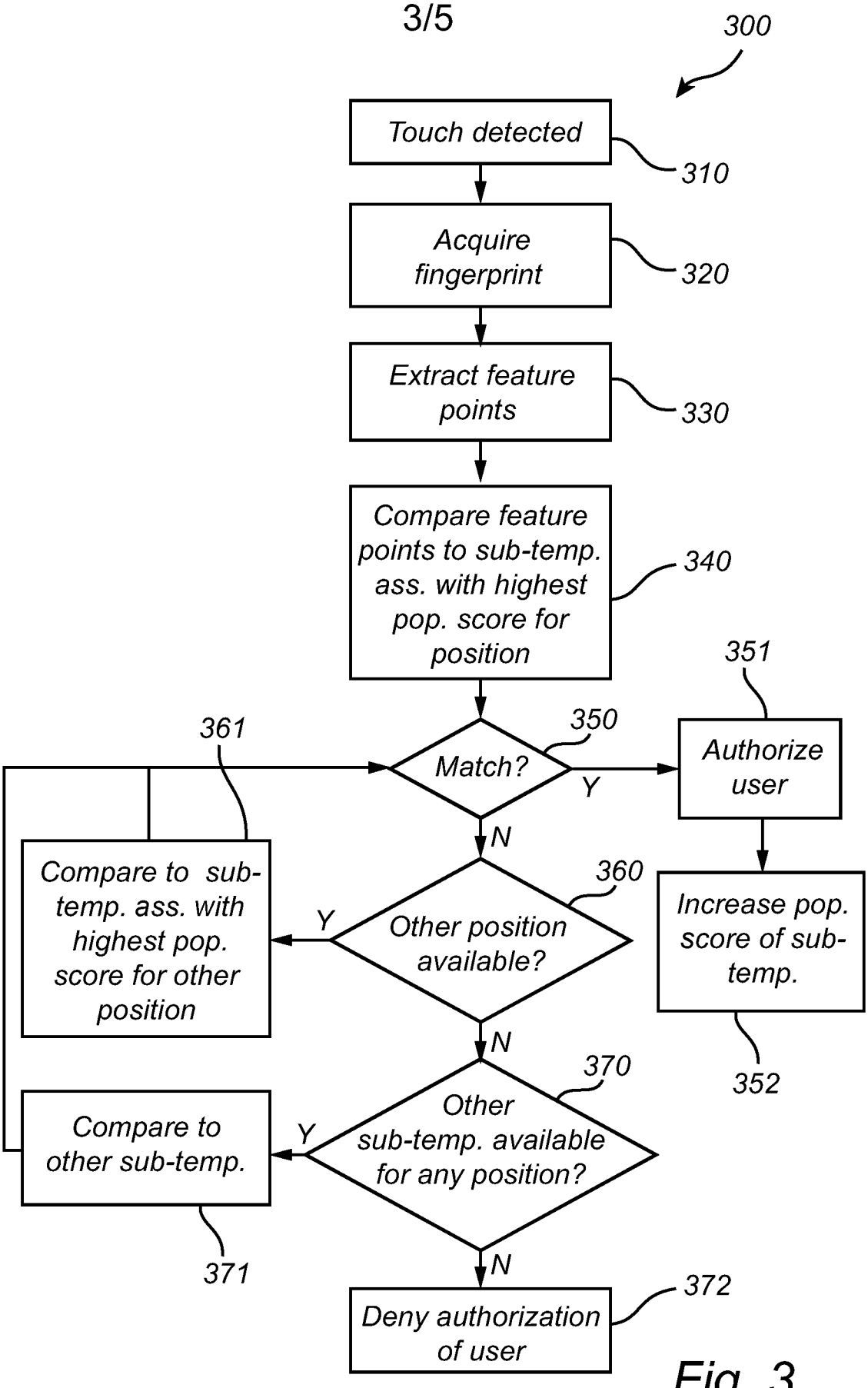
300
Touch detected
310
Acquire fingerprint
320
Extract feature points
330
Compare feature points to sub-temp. ass. with highest pop. score for position
340
351
361
350
Match?
Y
Authorize user
N
Compare to sub-temp. ass. with highest pop. score for other position
360
Y
Other position available?
Increase pop. score of sub-temp.
352
N
370
Compare to other sub-temp.
Y
Other sub-temp. available for any position?
371
N
372
Deny authorization of user

Fig. 3

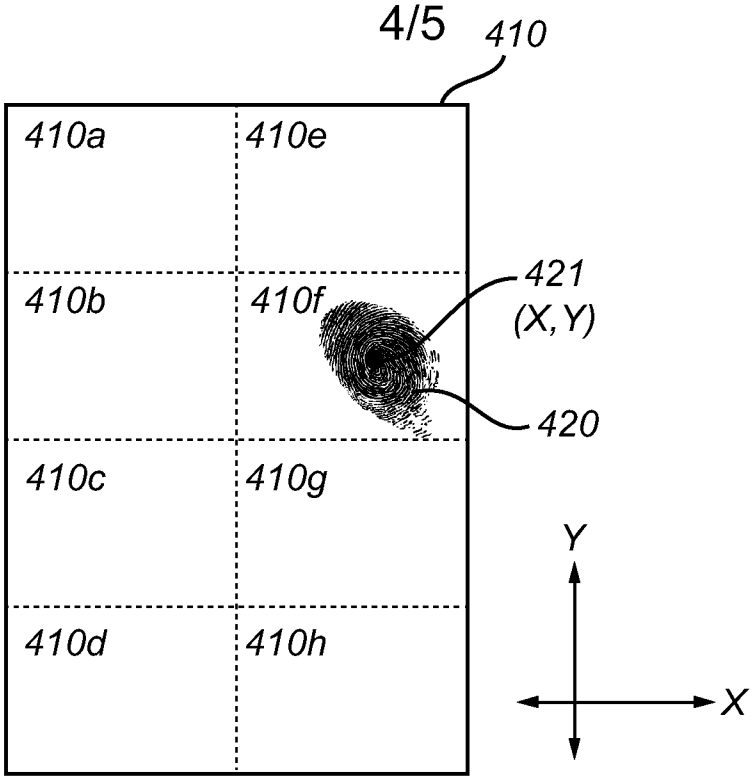
410
410a
410e
410b
410f
421
(X,Y)
420
410c
410g
410d
410h
Y
X

Fig. 4

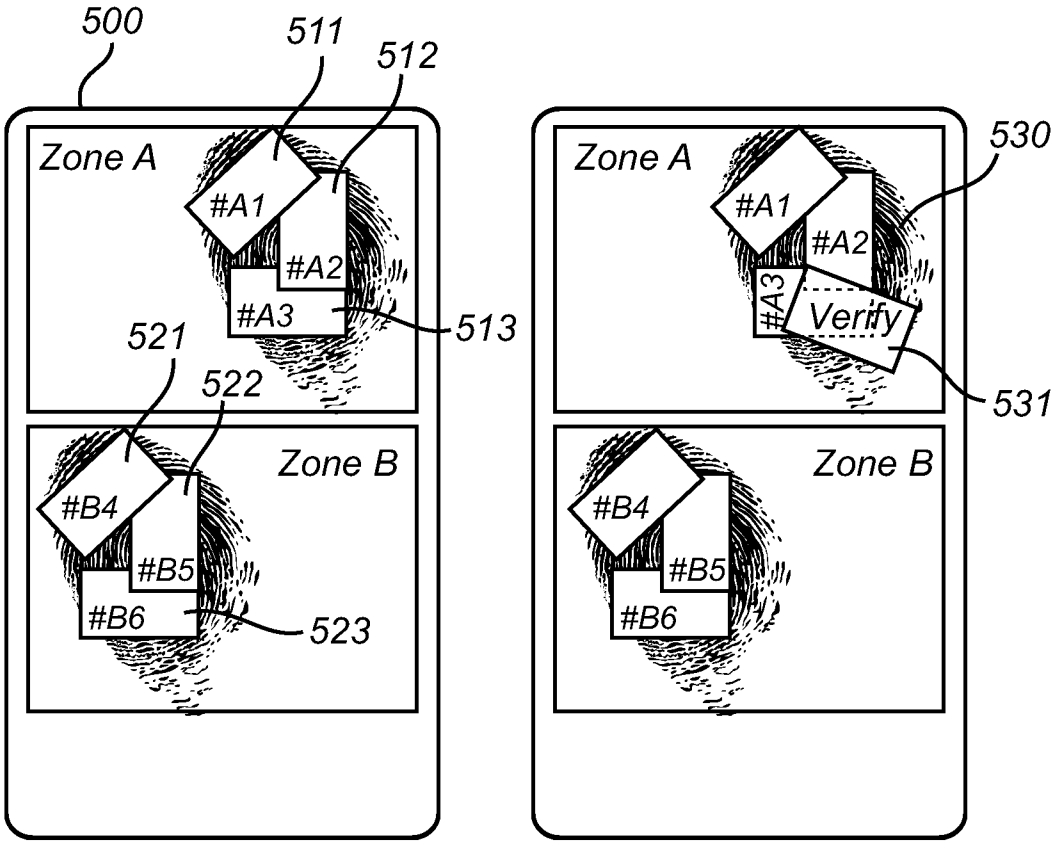
500
511
512
Zone A
#A1
#A2
#A3
513
521
522
Zone B
#B4
#B5
#B6
523
530
Verify
531

Fig. 5

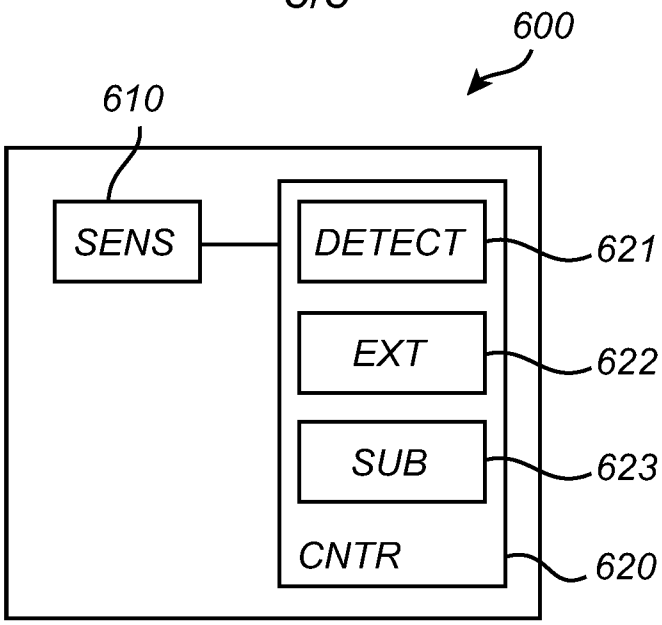
600
610
SENS
DETECT
621
EXT
622
SUB
623
CNTR
620

Fig. 6

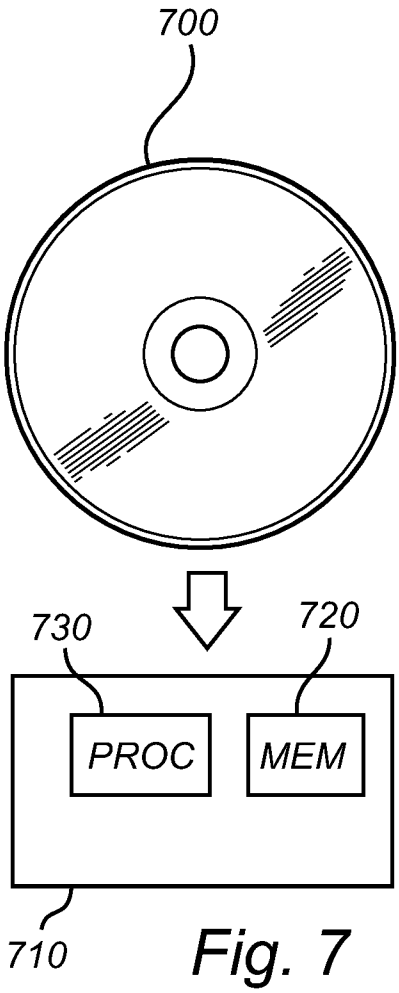
700
730
720
PROC
MEM
710

Fig. 7

**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/SE2018/051367

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: G06F, G06K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, PAJ, WPI data, COMPENDEX, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
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☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 04-02-2019 | 04-02-2019 |
| Name and mailing address of the ISA/SE<br>Patent- och registreringsverket<br>Box 5055<br>S-102 42 STOCKHOLM<br>Facsimile No. + 46 8 666 02 86 | Authorized officer<br>Erik Westin<br>Telephone No. + 46 8 782 28 00 |

Form PCT/ISA/210 (second sheet) (January 2015)

**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/SE2018/051367

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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International application No.
PCT/SE2018/051367

**Continuation of:** second sheet

**International Patent Classification (IPC)**

***G06K 9/00*** (2006.01)
***G06F 3/043*** (2006.01)
*G06F 21/32* (2013.01)

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| | | | | JP | 2017504853 | A | 09/02/2017 |