

What is claimed is:

1. A method of controlling access to a secure system, the method comprising:
 - obtaining, by one or more image acquisition devices, a first image of a portion of a human body under illumination by electromagnetic radiation in a first wavelength range, the first image including information on skin texture of the portion of the human body;
 - obtaining, by the one or more image acquisition devices, a second image of the portion of the human body under illumination by electromagnetic radiation in a second wavelength range, the second image including information on subcutaneous or deeper vasculature in the portion of the human body;
 - generating, by one or more processing devices, ~~a composite template that combines information from the first image with information from the second image; using a machine-learning based process with a deep multi-biometric convolutional neural network (CNN), a composite template by non-linear fusion of (i) information from the first image with (ii) information from the second image, wherein generating the composite template comprises accepting the information from the first image and the information from the second image as inputs of the deep multi-biometric CNN, processing each of the inputs through different layers of the deep multi-biometric CNN by processing first inputs associated with the information from the first image using at least one first layer of the deep multi-biometric CNN and processing second inputs associated with the information from the second image using at least one second layer of the deep multi-biometric CNN, and merging layers associated with the inputs in the deep multi-biometric CNN by merging the at least one first layer and the at least one second layer to obtain fused features as the composite template, wherein the at least one first layer and the at least one second layer are different from each other and separately trained using two different~~

spectra of the portion of the human body that correspond to the first wavelength range and the second wavelength range;

determining that one or more metrics representing a similarity between the composite template and an enrollment template satisfy a threshold condition; and

responsive to determining that the one or more metrics representing the similarity between the composite template and the enrollment template satisfy a threshold condition, providing access to the secure system.

2. The method of claim 1, wherein generating the composite template comprises using a classifier configured to fuse the information from the first image and the information from the second image at one of an early fusion level, an intermediate fusion level, or a late fusion level.

3. The method of claim 2, wherein generating the composite template comprises first generating a first template from the first image and generating a second template from the second image.

4. The method of claim 3, wherein generating the templates for the first and second images comprises extracting, from the first and second images, a respective portion representative of a hand.

5. The method of claim 4, wherein extracting a portion representative of the hand comprises excluding at least partially accessories worn on the hand.

6. The method of claim 1, wherein the skin texture ~~comprise~~comprises micro features.

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7. The method of claim 1, wherein the skin texture ~~comprise~~comprises at least one of: freckles, spots, moles, lines, ~~and~~or wrinkles.
8. The method of claim 1, wherein the portion of the human body comprises a hand.
9. The method of claim 8, wherein obtaining ~~a~~the first image and the second image of the hand comprises capturing double-sided images of the hand.
10. The method of claim 1, wherein the first wavelength range comprises a wavelength range between 380 and 600 nanometers.
11. The method of claim 1, wherein the second wavelength range comprises a wavelength range between 700 and 1000 nanometers.
12. The method of claim 1, wherein the one or more metrics comprise one or more of a cosine similarity metric, a Euclidean distance metric, a Mahalanobis distance metric, or a learned data-driven similarity metric.
13. A system comprising:
at least one processing device associated with a secure system; and

a memory communicatively coupled to the at least one processing device, the memory storing instructions which, when executed, cause the at least one processing device to perform operations comprising:

obtaining, from one or more image acquisition devices, a first image of a portion of a human body under illumination by electromagnetic radiation in a first wavelength range, the first image including information on skin texture of the portion of the human body;

obtaining, from the one or more image acquisition devices, a second image of the portion of the human body under illumination by electromagnetic radiation in a second wavelength range, the second image including information on subcutaneous vasculature in the portion of the human body;

~~generating, by the at least one processing device, a composite template that combines information from the first image with information from the second image;~~
generating, using a machine-learning based process with a deep multi-biometric convolutional neural network (CNN), a composite template by non-linear fusion of (i) information from the first image with (ii) information from the second image, wherein generating the composite template comprises accepting the information from the first image and the information from the second image as inputs of the deep multi-biometric CNN, processing each of the inputs through different layers of the deep multi-biometric CNN by processing first inputs associated with the information from the first image using at least one first layer of the deep multi-biometric CNN and processing second inputs associated with the information from the second image using at least one second layer of the deep multi-biometric CNN, and merging layers associated with the inputs in the deep multi-biometric CNN by merging the at least one first layer and the at least one second layer to obtain fused features as the composite template, wherein the at least one first layer and the at least one second layer are different from each other and separately trained using two different spectra of the portion of the human body that correspond to the first wavelength range and the second wavelength range;

determining that one or more metrics representing a similarity between the composite template and an enrollment template satisfy a threshold condition; and

_____ responsive to determining that the one or more metrics representing the similarity
_____ between the composite template and the enrollment template satisfy a threshold condition,
providing access to the secure system.

14. The system of claim 13, further comprising:

_____ an image acquisition device;

_____ a first illumination source configured to radiate light in the first wavelength range;

and

_____ a second illumination source configured to radiate light in the second wavelength
range.

15. _____ The system of claim 14, wherein the image acquisition device comprises a field of view
facing the second illumination source such that the portion of the human body is between the
image acquisition device and the second illumination source.

16. The system of claim 13, wherein generating the composite template comprises using a
classifier configured to fuse the information from the first image and the information from the
second image at one of an early fusion level, an intermediate fusion level, or a late fusion level.

17. The system of claim 16, wherein generating the composite template comprises first
generating a first template from the first image and generating a second template from the second
image.

18. The system of claim 17, wherein generating the template for the first and second images comprises extracting, from the first and second images, a respective portion representative of a hand.

19. The system of claim 13, wherein the one or more metrics comprise one or more of a cosine similarity metric, a Euclidean distance metric, a Mahalanobis distance metric, or a learned data-driven similarity metric.

20. The system of claim 13, wherein the skin texture ~~comprise~~comprises micro features.

21. The method of claim 1, wherein generating the composite template comprises obtaining a fully connected and soft-max layer for classification with a merged layer.

22. The method of claim 1, wherein the composite template is a non-reversible template that comprises a nonlinear combination of local features of the information from the first image and the information from the second image followed by a matching operation between the local features across corresponding localities.