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Lotti et al.

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(54) **USING TWO-DIMENSIONAL IMAGES TO IDENTIFY SEARCH PARAMETERS FOR A SEARCH OF FALSE EYELASHES**

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(51) **Int. Cl.**

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G06T 7/60	(2017.01)
G06T 17/00	(2006.01)
G06V 40/16	(2022.01)

(52) **U.S. Cl.**
CPC ***G06T 11/60*** (2013.01); ***G06T 7/60*** (2013.01); ***G06T 17/00*** (2013.01); ***G06V 40/171*** (2022.01); *G06V 2201/07* (2022.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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132/201
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382/118
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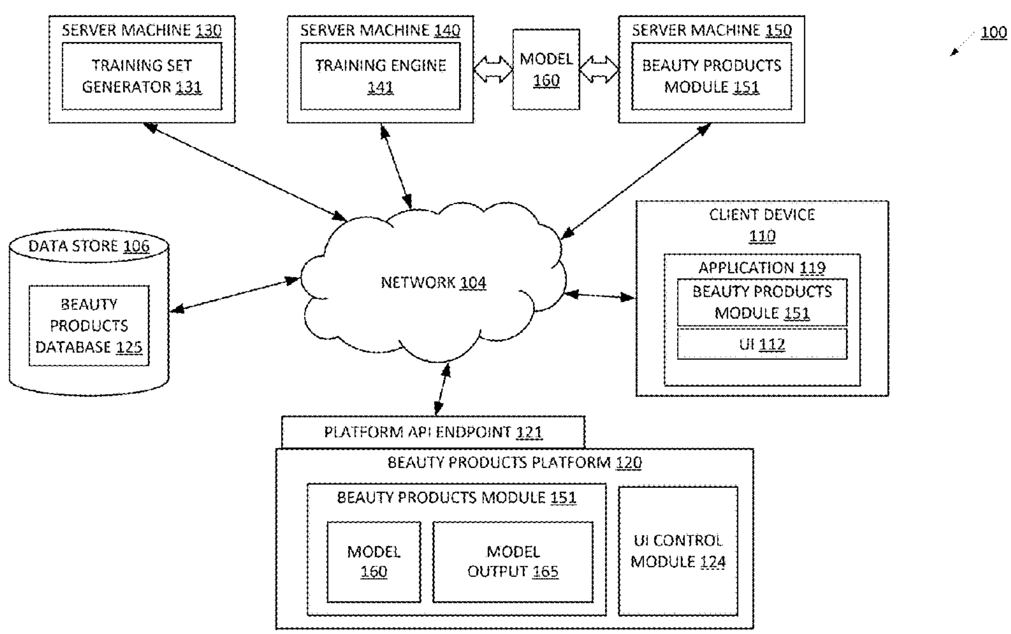
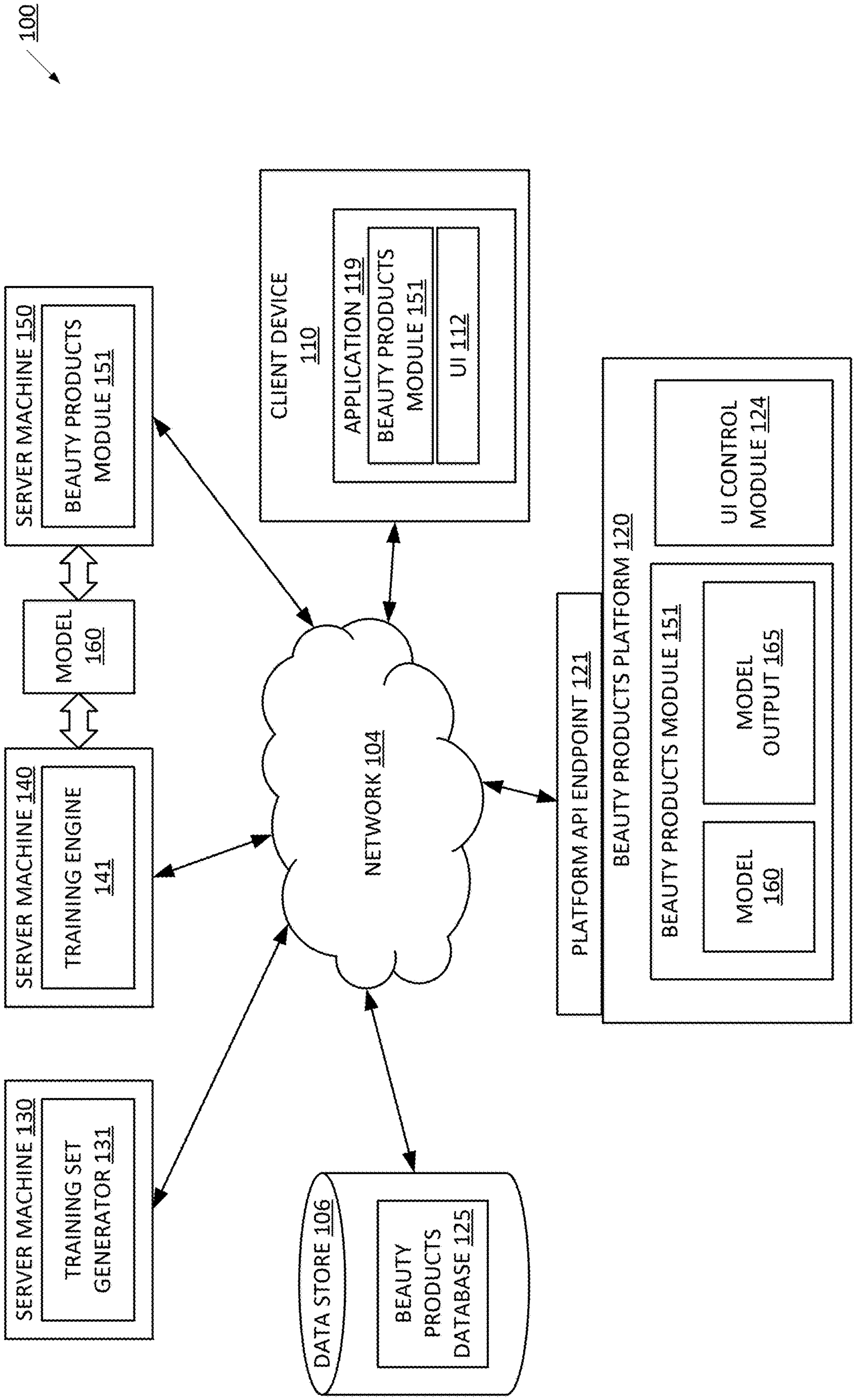
(57) **ABSTRACT**

Two-dimensional (2D) image data corresponding to a 2D image of an eye area of a subject is received. A three-dimensional (3D) model of the eye area is generated using the 2D image data. A relationship between a first landmark of the 3D model and a second landmark of the 3D model is determined. The first landmark represents a first facial feature of the eye area, and the second landmark represents a second facial feature of the eye area. A subset of a plurality of false eyelashes is identified among a plurality of false eyelashes based on the relationship between the first landmark and the second landmark of the 3D model.

20 Claims, 18 Drawing Sheets

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SERVER MACHINE 150
BEAUTY PRODUCTS MODULE 151
MODEL 160
SERVER MACHINE 140
TRAINING ENGINE 141
SERVER MACHINE 130
TRAINING SET GENERATOR 131
CLIENT DEVICE 110
APPLICATION 119
BEAUTY PRODUCTS MODULE 151
UI 112
NETWORK 104
DATA STORE 106
BEAUTY PRODUCTS DATABASE 125
PLATFORM API ENDPOINT 121
BEAUTY PRODUCTS PLATFORM 120
BEAUTY PRODUCTS MODULE 151
MODEL 160
MODEL OUTPUT 165
UI CONTROL MODULE 124

FIG. 1

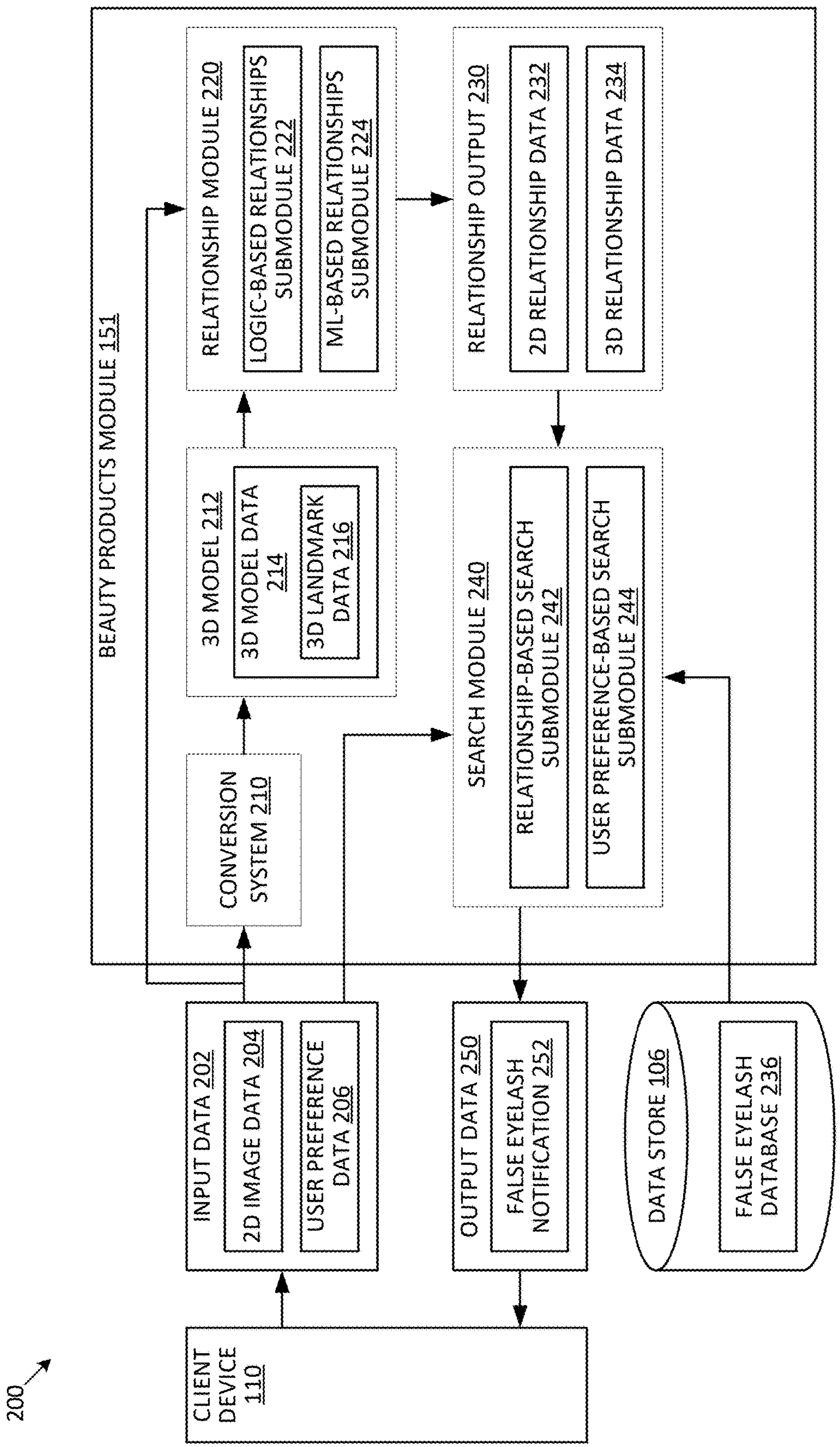
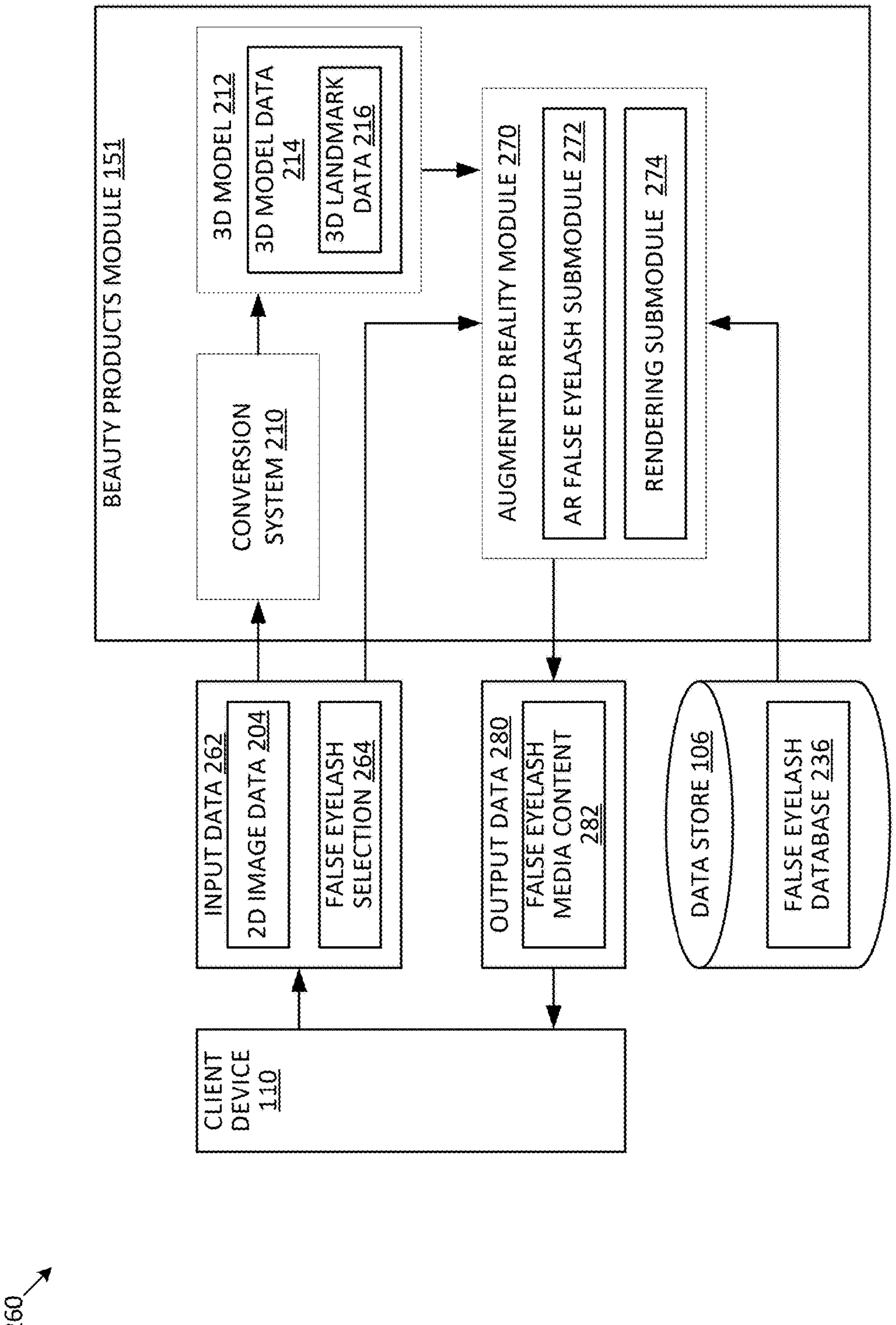

200
CLIENT DEVICE 110
INPUT DATA 202
2D IMAGE DATA 204
USER PREFERENCE DATA 206
OUTPUT DATA 250
FALSE EYELASH NOTIFICATION 252
DATA STORE 106
FALSE EYELASH DATABASE 236
BEAUTY PRODUCTS MODULE 151
CONVERSION SYSTEM 210
3D MODEL 212
3D MODEL DATA 214
3D LANDMARK DATA 216
RELATIONSHIP MODULE 220
LOGIC-BASED RELATIONSHIPS SUBMODULE 222
ML-BASED RELATIONSHIPS SUBMODULE 224
RELATIONSHIP OUTPUT 230
2D RELATIONSHIP DATA 232
3D RELATIONSHIP DATA 234
SEARCH MODULE 240
RELATIONSHIP-BASED SEARCH SUBMODULE 242
USER PREFERENCE-BASED SEARCH SUBMODULE 244

FIG. 2A


260
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3D MODEL 212
3D MODEL DATA 214
3D LANDMARK DATA 216
AUGMENTED REALITY MODULE 270
AR FALSE EYELASH SUBMODULE 272
RENDERING SUBMODULE 274
INPUT DATA 262
2D IMAGE DATA 204
FALSE EYELASH SELECTION 264
OUTPUT DATA 280
FALSE EYELASH MEDIA CONTENT 282
DATA STORE 106
FALSE EYELASH DATABASE 236
CLIENT DEVICE 110

FIG. 2B

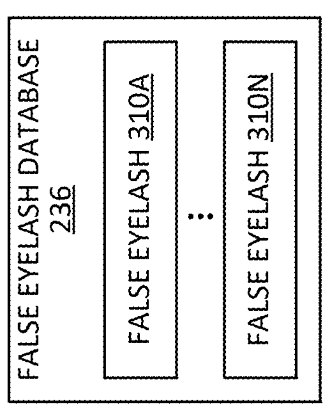


FIG. 3A

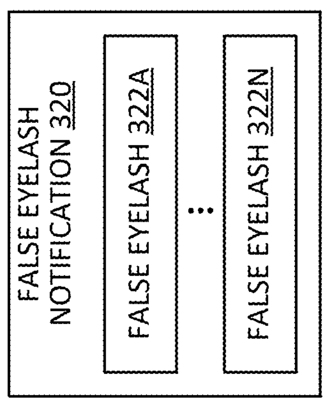


FIG. 3B

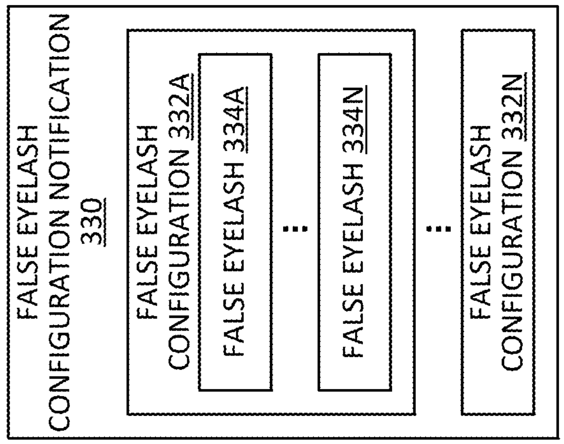


FIG. 3C

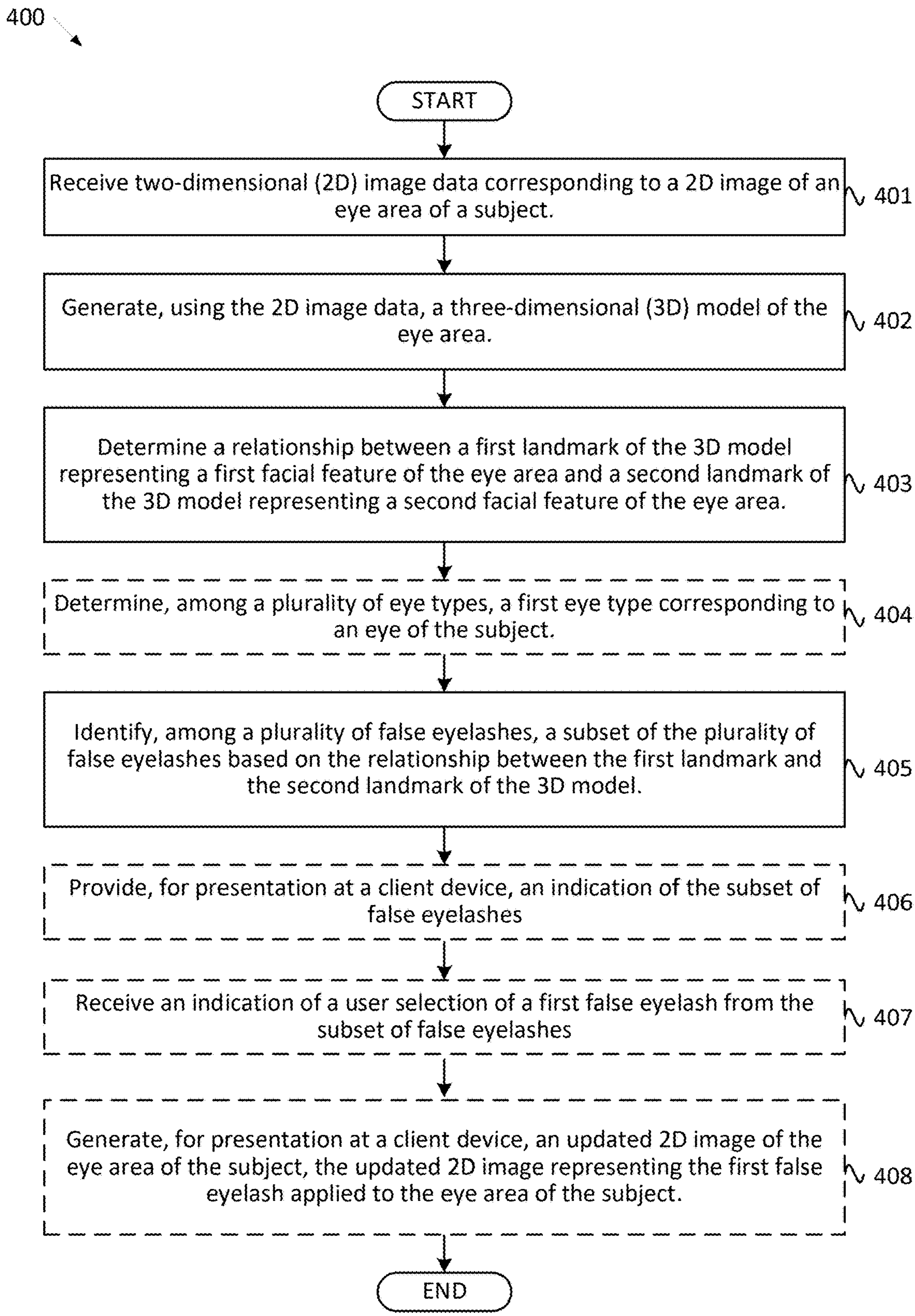
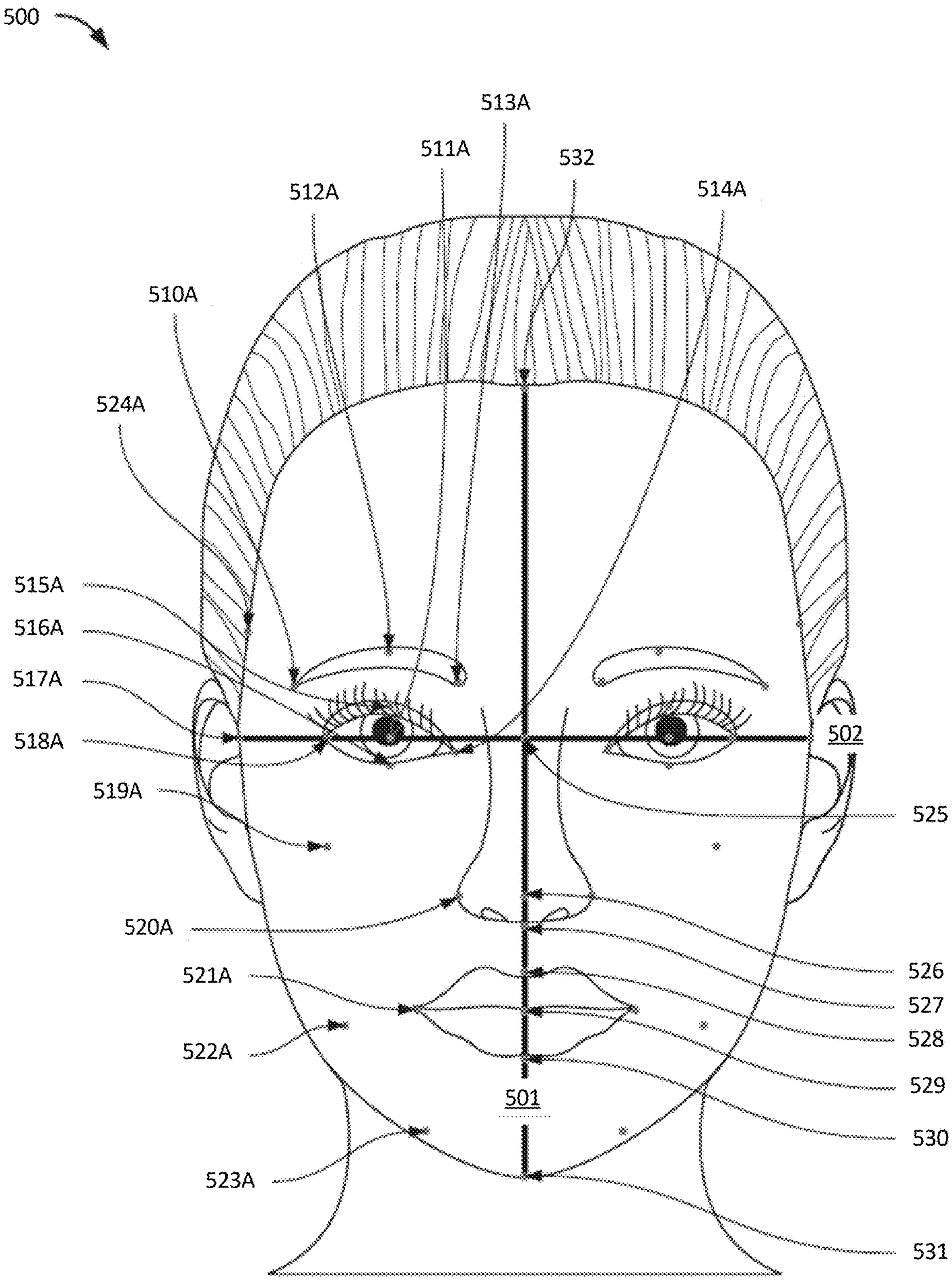

400
START
Receive two-dimensional (2D) image data corresponding to a 2D image of an eye area of a subject.
401
Generate, using the 2D image data, a three-dimensional (3D) model of the eye area.
402
Determine a relationship between a first landmark of the 3D model representing a first facial feature of the eye area and a second landmark of the 3D model representing a second facial feature of the eye area.
403
Determine, among a plurality of eye types, a first eye type corresponding to an eye of the subject.
404
Identify, among a plurality of false eyelashes, a subset of the plurality of false eyelashes based on the relationship between the first landmark and the second landmark of the 3D model.
405
Provide, for presentation at a client device, an indication of the subset of false eyelashes
406
Receive an indication of a user selection of a first false eyelash from the subset of false eyelashes
407
Generate, for presentation at a client device, an updated 2D image of the eye area of the subject, the updated 2D image representing the first false eyelash applied to the eye area of the subject.
408
END

FIG. 4



500
513A
511A
532
512A
514A
510A
524A
515A
516A
517A
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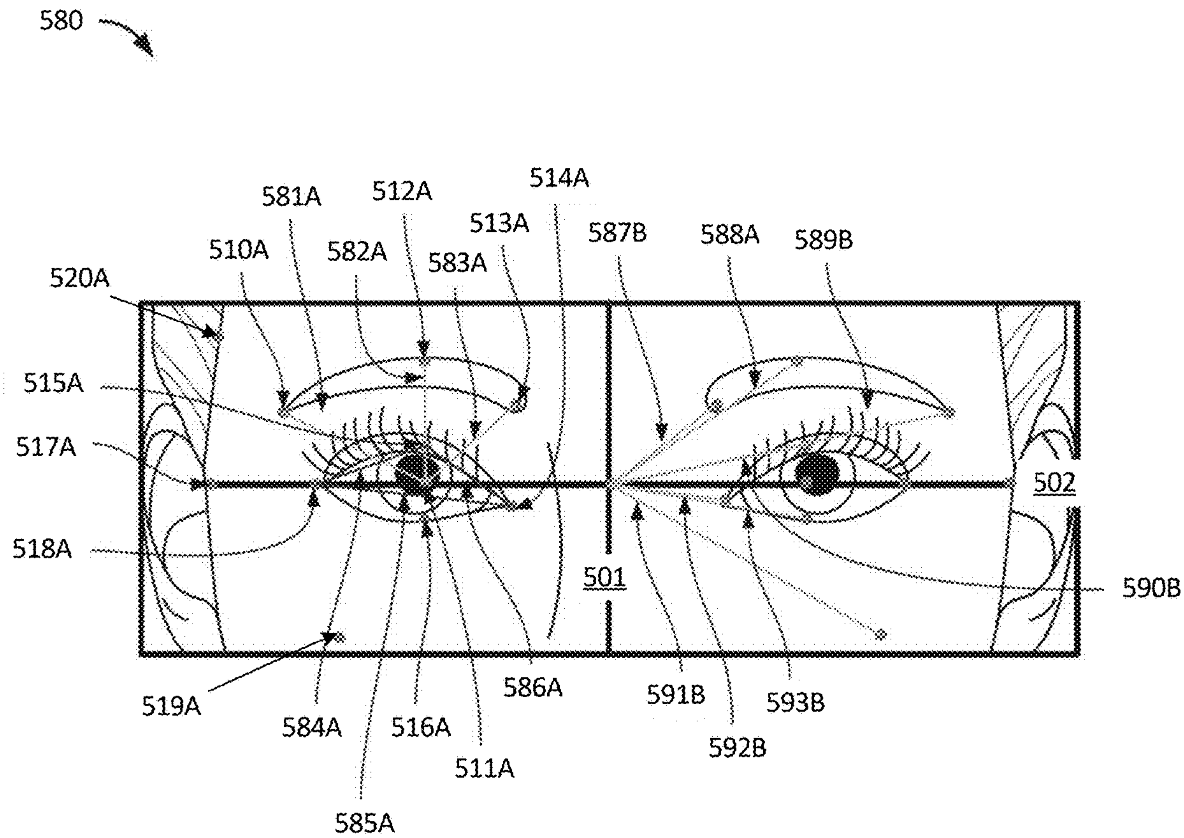
520A
526
521A
527
528
522A
529
501
530
523A
531

FIG. 5A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590B
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593B
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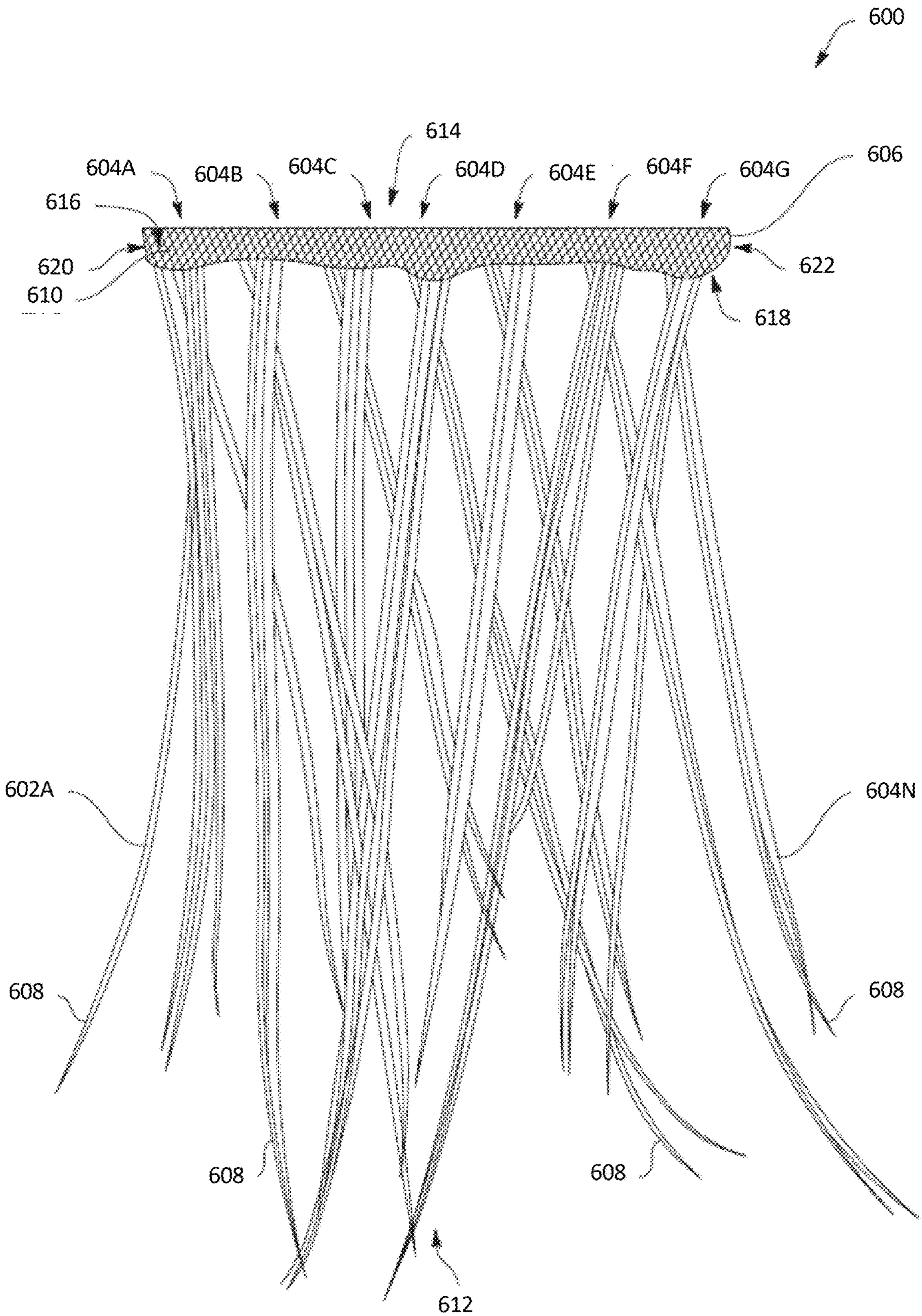
585A

FIG. 5B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614
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604E
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602A
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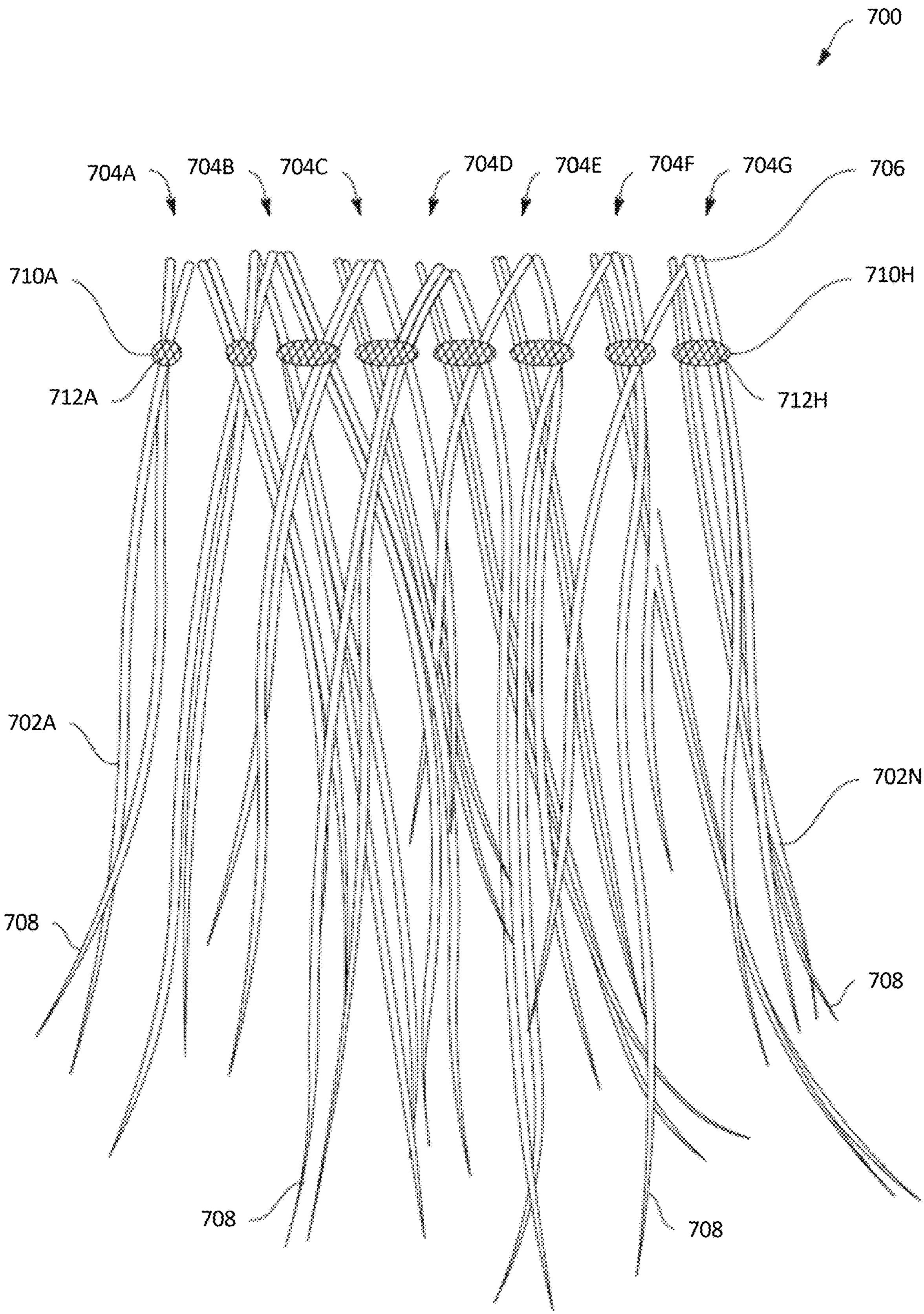
608
608
608
608
608
612

FIG. 6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704C
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704E
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710H
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712H
702A
702N
708
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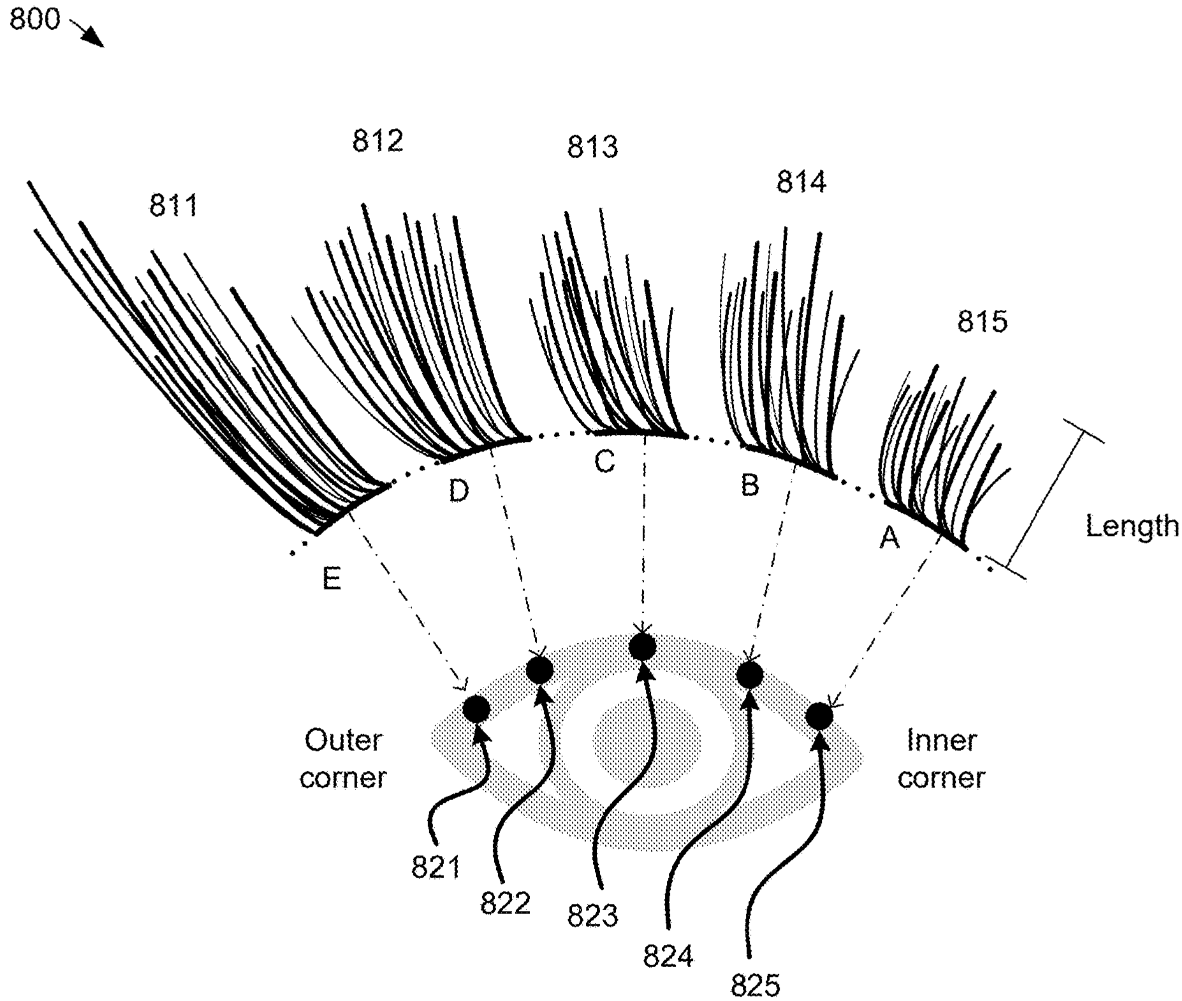
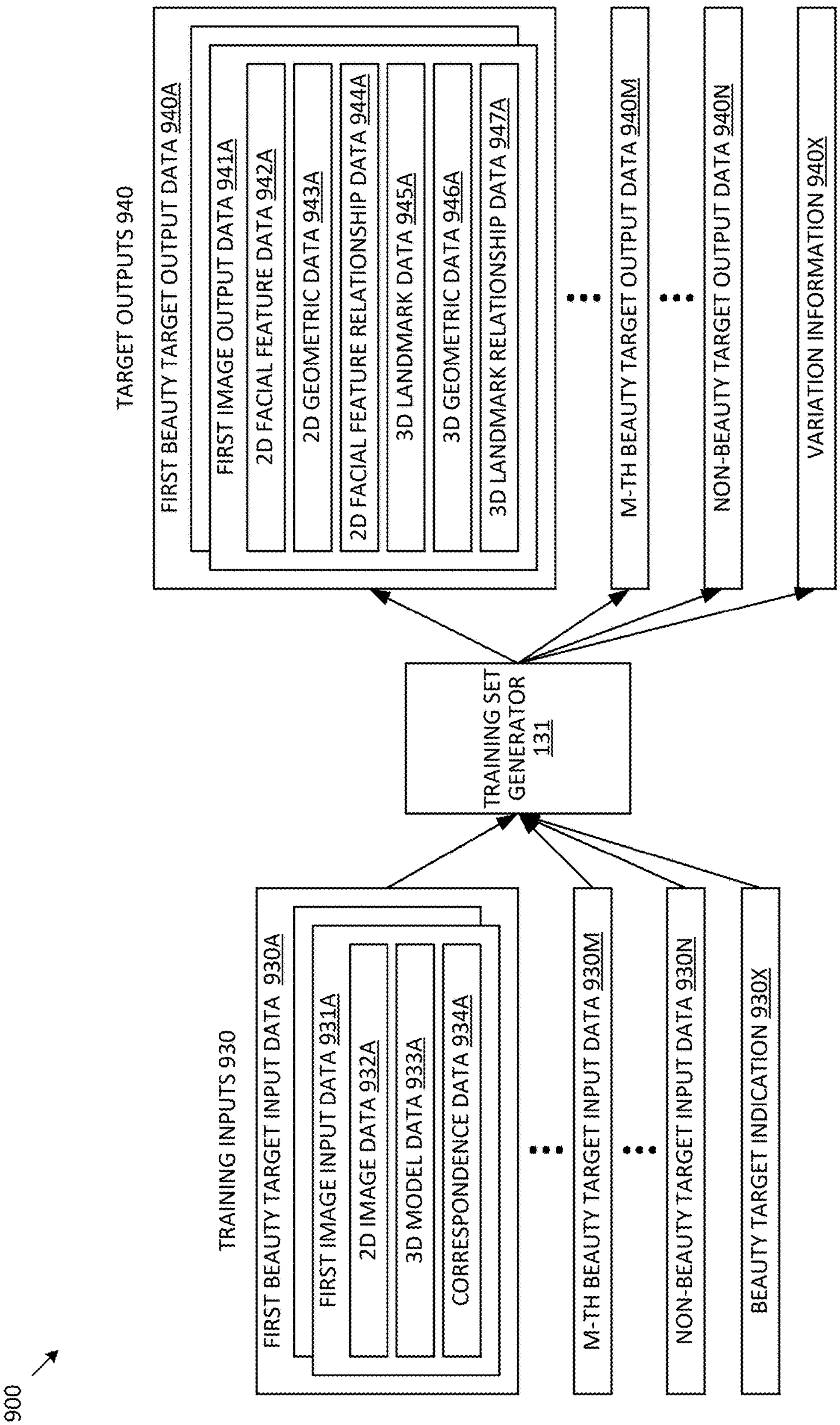
708
708

FIG. 7



Example lash configuration information (from inner corner to outer corner):
Style info: X, X, X, X, X
Length info (mm): 8, 9, 10, 11, 12
Color info: Black
Position info: A, B, C, D, E
Location info: Arrange from inner corner (start) to outer corner (end) 835

FIG. 8


900
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FIRST BEAUTY TARGET INPUT DATA 930A
FIRST IMAGE INPUT DATA 931A
2D IMAGE DATA 932A
3D MODEL DATA 933A
CORRESPONDENCE DATA 934A
M-TH BEAUTY TARGET INPUT DATA 930M
NON-BEAUTY TARGET INPUT DATA 930N
BEAUTY TARGET INDICATION 930X
TRAINING SET GENERATOR 131
TARGET OUTPUTS 940
FIRST BEAUTY TARGET OUTPUT DATA 940A
FIRST IMAGE OUTPUT DATA 941A
2D FACIAL FEATURE DATA 942A
2D GEOMETRIC DATA 943A
2D FACIAL FEATURE RELATIONSHIP DATA 944A
3D LANDMARK DATA 945A
3D GEOMETRIC DATA 946A
3D LANDMARK RELATIONSHIP DATA 947A
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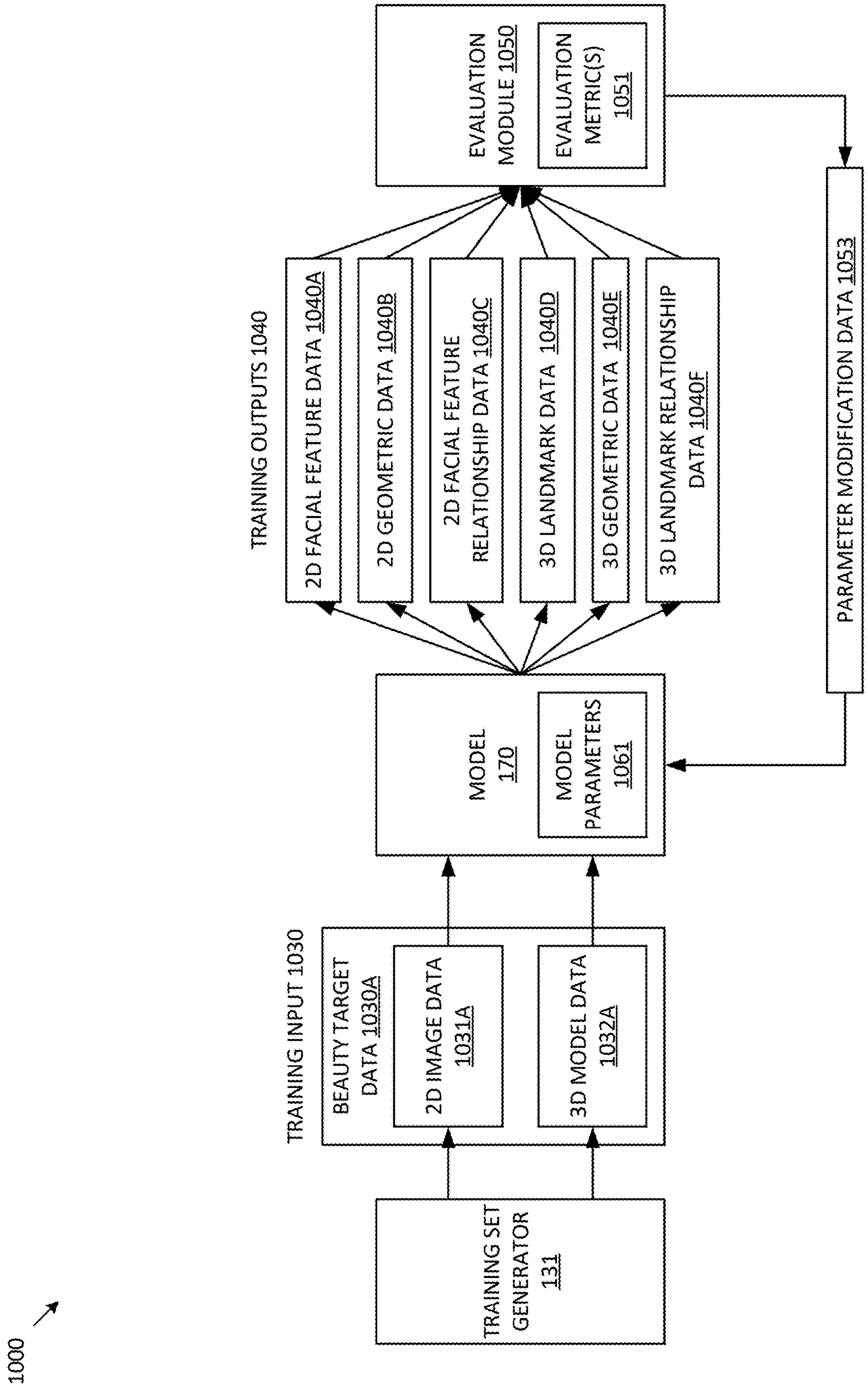
VARIATION INFORMATION 940X

FIG. 9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3D MODEL DATA 1032A
MODEL 170
MODEL PARAMETERS 1061
TRAINING OUTPUTS 1040
2D FACIAL FEATURE DATA 1040A
2D GEOMETRIC DATA 1040B
2D FACIAL FEATURE RELATIONSHIP DATA 1040C
3D LANDMARK DATA 1040D
3D GEOMETRIC DATA 1040E
3D LANDMARK RELATIONSHIP DATA 1040F
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EVALUATION METRIC(S) 1051
PARAMETER MODIFICATION DATA 1053

FIG. 10

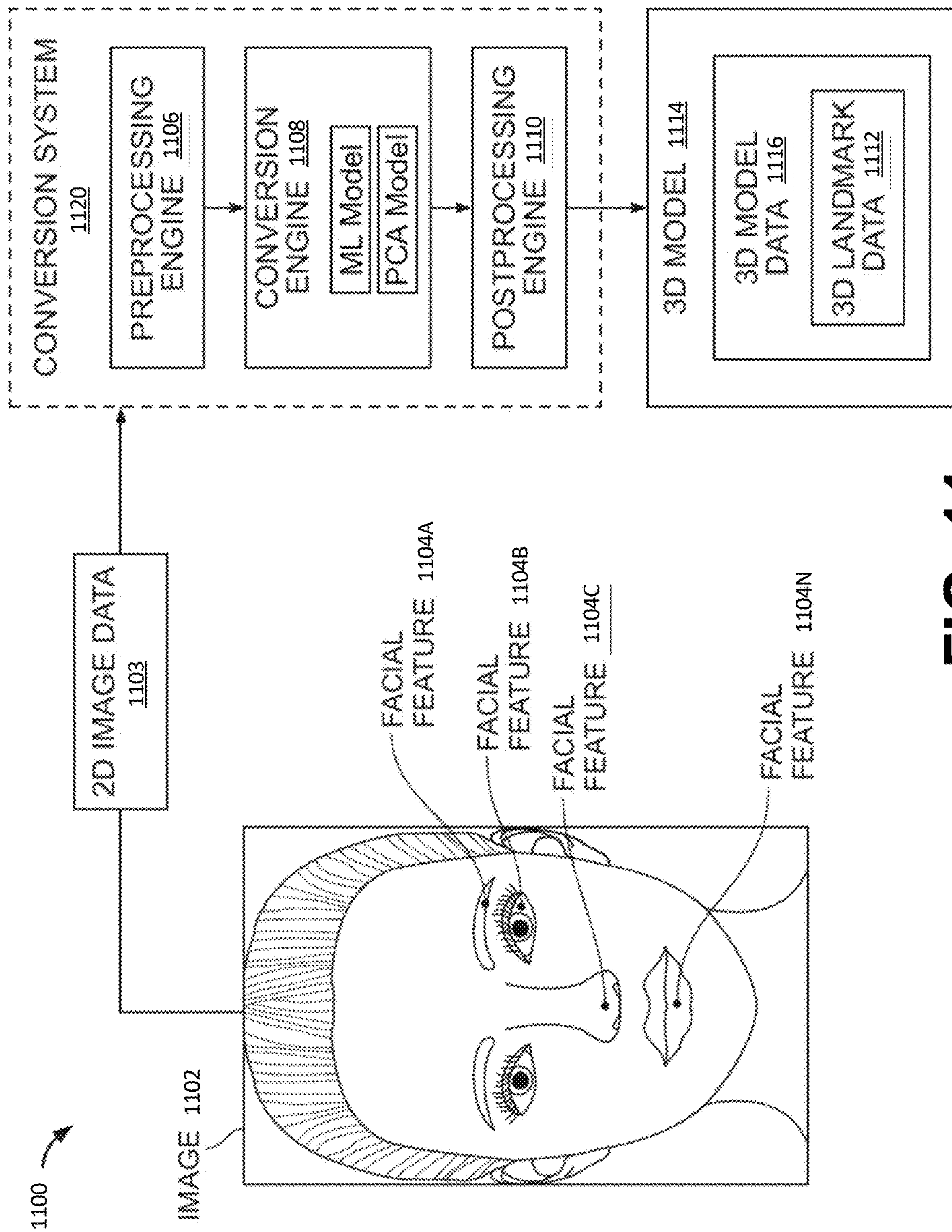

1100
IMAGE 1102
2D IMAGE DATA 1103
FACIAL FEATURE 1104A
FACIAL FEATURE 1104B
FACIAL FEATURE 1104C
FACIAL FEATURE 1104N
CONVERSION SYSTEM 1120
PREPROCESSING ENGINE 1106
CONVERSION ENGINE 1108
ML Model
PCA Model
POSTPROCESSING ENGINE 1110
3D MODEL 1114
3D MODEL DATA 1116
3D LANDMARK DATA 1112

FIG. 11

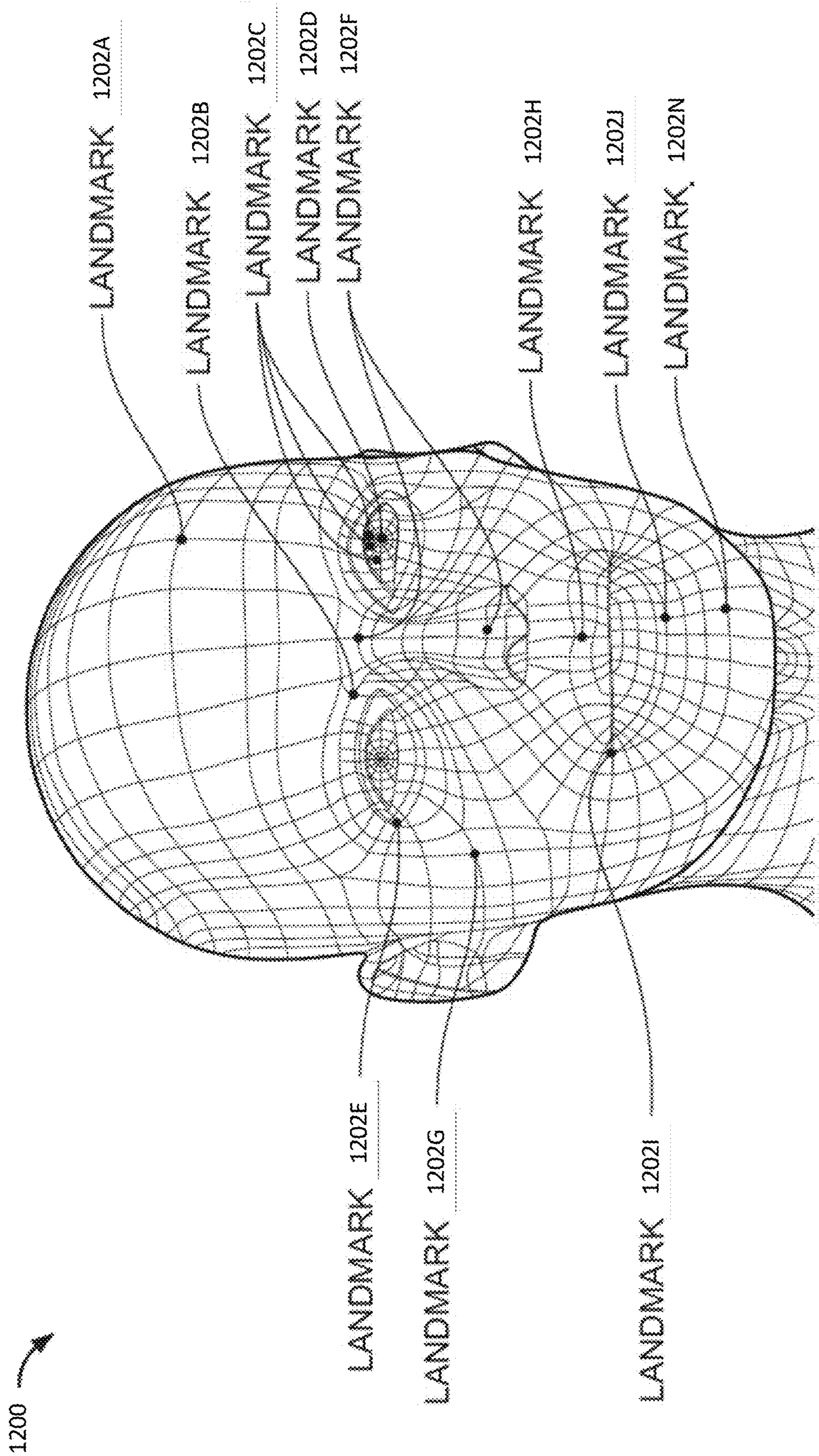

1200
LANDMARK 1202A
LANDMARK 1202B
LANDMARK 1202C
LANDMARK 1202D
LANDMARK 1202F
LANDMARK 1202H
LANDMARK 1202J
LANDMARK 1202N
LANDMARK 1202E
LANDMARK 1202G
LANDMARK 1202I

FIG. 12

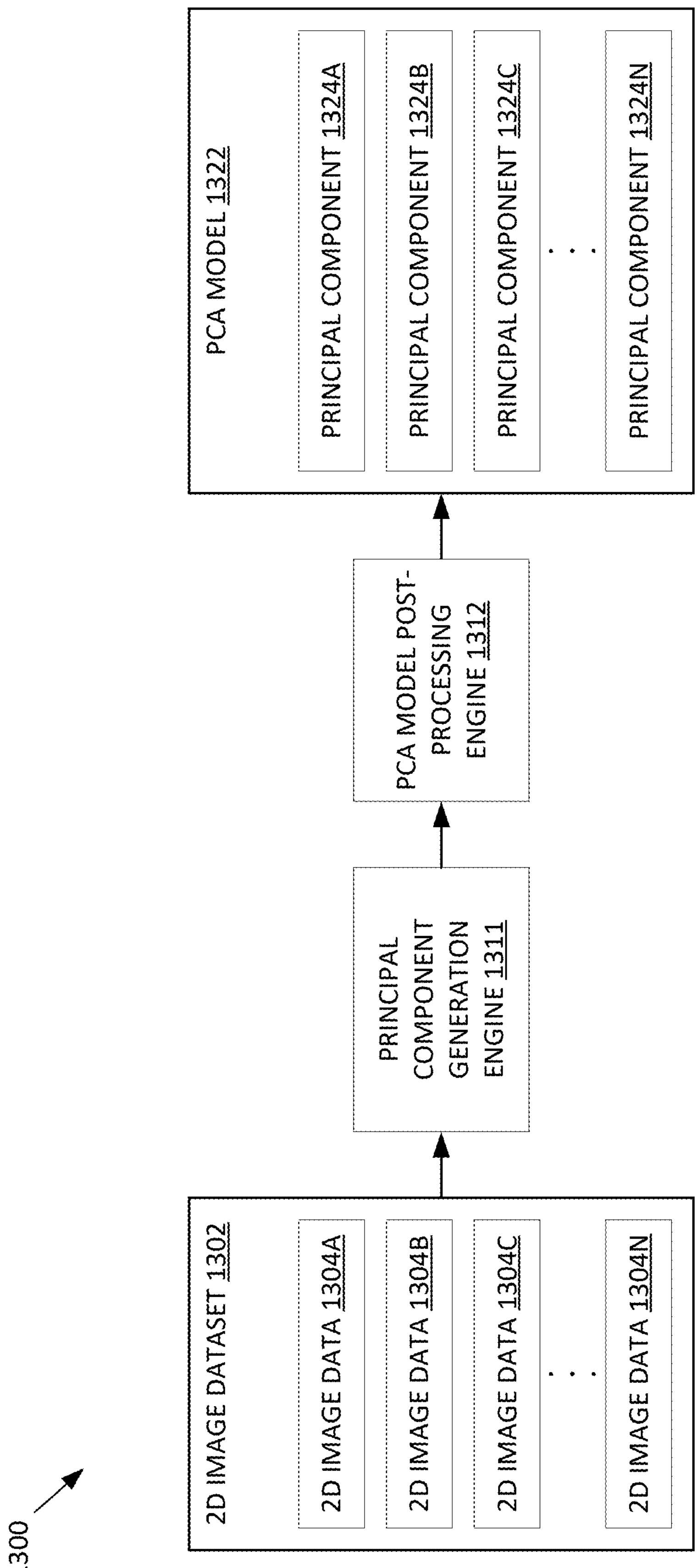
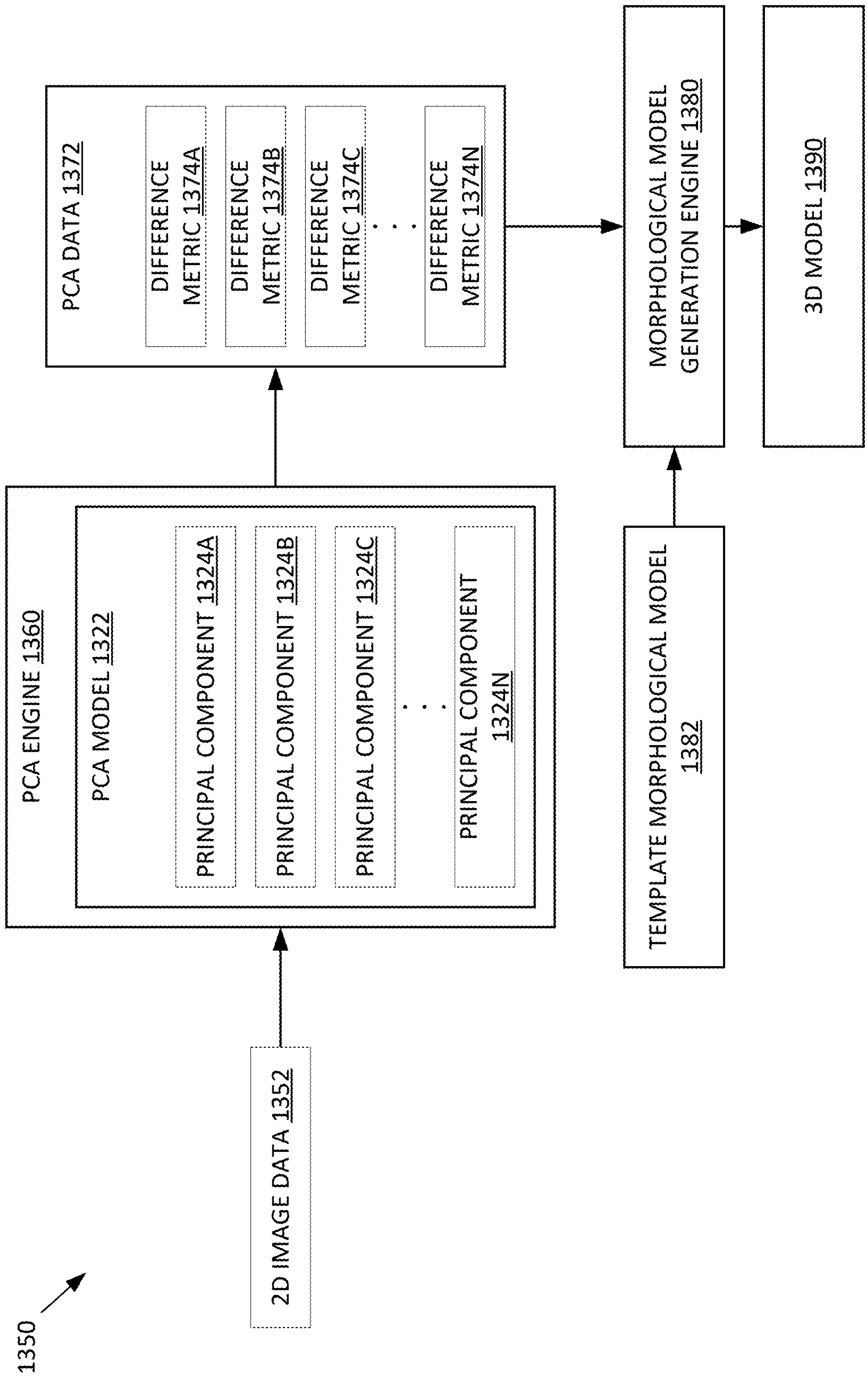

1300
2D IMAGE DATASET 1302
2D IMAGE DATA 1304A
2D IMAGE DATA 1304B
2D IMAGE DATA 1304C
. . .
2D IMAGE DATA 1304N
PRINCIPAL COMPONENT GENERATION ENGINE 1311
PCA MODEL POST-PROCESSING ENGINE 1312
PCA MODEL 1322
PRINCIPAL COMPONENT 1324A
PRINCIPAL COMPONENT 1324B
PRINCIPAL COMPONENT 1324C
. . .
PRINCIPAL COMPONENT 1324N

FIG. 13A


1350
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PRINCIPAL COMPONENT 1324C
. . .
PRINCIPAL COMPONENT 1324N
PCA DATA 1372
DIFFERENCE METRIC 1374A
DIFFERENCE METRIC 1374B
DIFFERENCE METRIC 1374C
. . .
DIFFERENCE METRIC 1374N
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MORPHOLOGICAL MODEL GENERATION ENGINE 1380
3D MODEL 1390

FIG. 13B

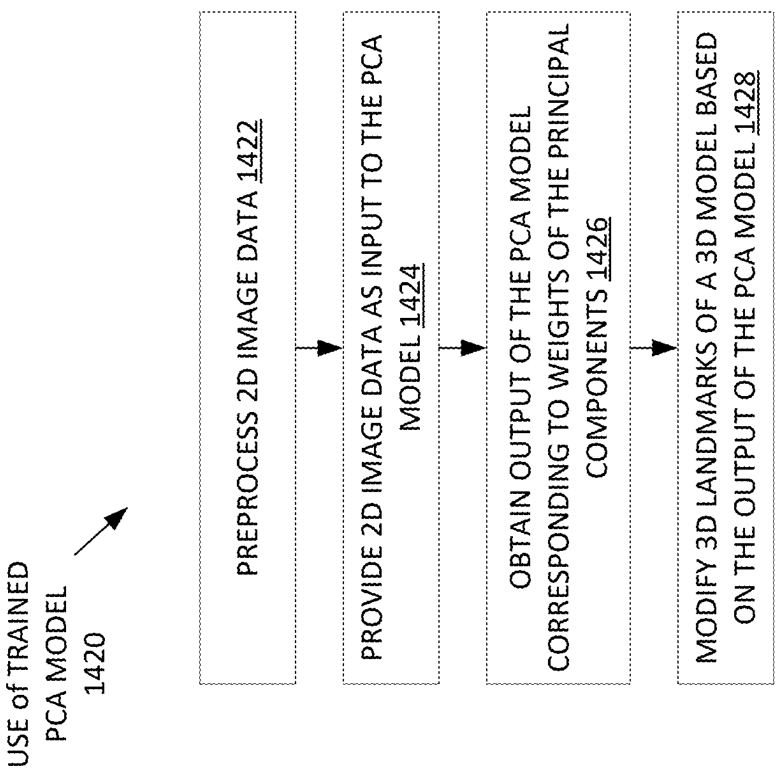

FIG. 14B

FIG. 14A

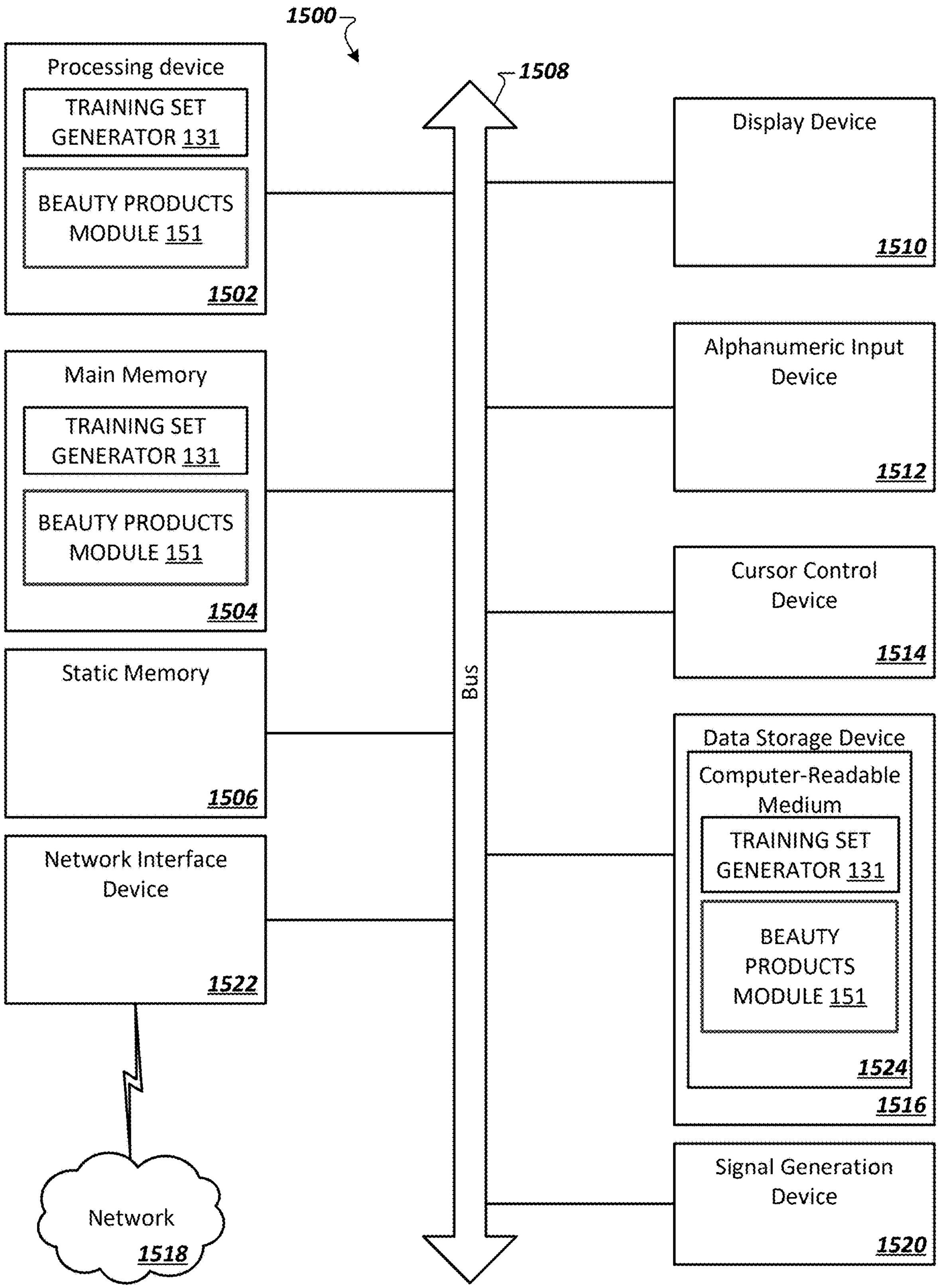
1500
1508
Processing device
TRAINING SET GENERATOR 131
BEAUTY PRODUCTS MODULE 151
1502
Main Memory
TRAINING SET GENERATOR 131
BEAUTY PRODUCTS MODULE 151
1504
Static Memory
1506
Network Interface Device
1522
Network
1518
Bus
Display Device
1510
Alphanumeric Input Device
1512
Cursor Control Device
1514
Data Storage Device
Computer-Readable Medium
TRAINING SET GENERATOR 131
BEAUTY PRODUCTS MODULE 151
1524
1516
Signal Generation Device
1520

FIG. 15

USING TWO-DIMENSIONAL IMAGES TO IDENTIFY SEARCH PARAMETERS FOR A SEARCH OF FALSE EYELASHES

TECHNICAL FIELD

Aspects and embodiments of the disclosure relate to data processing, and more specifically, to using two-dimensional (2D) images to identify search parameters for a search of false eyelashes.

BACKGROUND

Image processing can include the manipulation of digital images using various techniques and algorithms to improve their quality, extract useful information, or perform specific tasks.

SUMMARY

The following is a simplified summary of the disclosure in order to provide a basic understanding of some aspects of the disclosure. This summary is not an extensive overview of the disclosure. It is intended to neither identify key or critical elements of the disclosure, nor delineate any scope of the particular embodiments of the disclosure or any scope of the claims. Its sole purpose is to present some concepts of the disclosure in a simplified form as a prelude to the more detailed description that is presented later.

An embodiment of the disclosure provides a computer-implemented method for using two-dimensional (2D) images to identify search parameters for a search of false eyelashes, the method comprising: receiving two-dimensional (2D) image data corresponding to a 2D image of an eye area of a subject; generating, using the 2D image data, a three-dimensional (3D) model of the eye area; determining a relationship between a first landmark of the 3D model representing a first facial feature of the eye area and a second landmark of the 3D model representing a second facial feature of the eye area; and identifying, among a plurality of false eyelashes, a subset of the plurality of false eyelashes based on the relationship between the first landmark and the second landmark of the 3D model.

In some embodiments, identifying, among the plurality of false eyelashes, a subset of the plurality of false eyelashes based on the relationship between the first landmark and the second landmark further comprises: determining a range of values corresponding to a characteristic associated with the plurality of false eyelashes based on the determined relationship; and identifying, among the plurality of false eyelashes, the subset of the plurality of false eyelashes based at least in part on the range of values corresponding to the characteristic.

In some embodiments, the relationship between the first landmark of the 3D model and the second landmark of the 3D model comprises a geometrical relationship between the first landmark and the second landmark.

In some embodiments, determining the relationship between the first landmark of the 3D model representing the first facial feature of the eye area and the second landmark of the 3D model representing the second facial feature of the eye area, further comprises identifying the first landmark and the second landmark on the 3D model.

In some embodiments, determining the relationship between the first landmark of the 3D model representing the first facial feature of the eye area and the second landmark of the 3D model representing the second facial feature of the eye area, further comprises determining a distance between the first landmark and the second landmark, the distance representing at least part of the relationship between the first landmark and the second landmark.

In some embodiments, the first facial feature comprises an eyebrow of the subject and the second facial feature comprises an eye of the subject.

In some embodiments, the method further comprises: providing, for presentation at a client device, an indication of the subset of false eyelashes; receiving an indication of a user selection of a first false eyelash from the subset of false eyelashes; and generating, for presentation at a client device, an updated 2D image of the eye area of the subject, the updated 2D image representing the first false eyelash applied to the eye area of the subject.

In some embodiments, the subset of false eyelashes comprise artificial lash extensions designed for application at an underside of natural eyelashes, and wherein the updated 2D image represents one or more of the artificial lash extensions applied to the underside of natural lashes of the subject.

In some embodiments, the method further comprises: determining, among a plurality of eye types, a first eye type corresponding to an eye of the subject, wherein identifying, among the plurality of false eyelashes, the subset of the plurality of false eyelashes is based at least in part on the eye type corresponding to the eye of the subject.

In some embodiments, the method further comprises: receiving, among a plurality of lash styles, a user preference identifying a first lash style, wherein identifying, among the plurality of false eyelashes, the subset of the plurality of false eyelashes is based at least in part on the user selection identifying the first lash style.

In some embodiments, generating, using the 2D image data, the 3D model of the eye area comprises: providing the 2D image data as input to a conversion system; and obtaining one or more outputs of the conversion system, the one or more outputs corresponding to the 3D model.

A further embodiment(s) of the disclosure provides a system comprising: a memory; and a processing device, coupled to the memory, the processing device to perform a method according to any aspect or embodiment described herein. A further embodiment(s) of the disclosure provides a computer-readable medium comprising instructions that, responsive to execution by a processing device, cause the processing device to perform operations comprising a method according to any aspect or embodiment described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

Aspects and embodiments of the disclosure will be understood more fully from the detailed description given below and from the accompanying drawings of various aspects and embodiments of the disclosure, which, however, should not be taken to limit the disclosure to the specific aspects or embodiments, but are for explanation and understanding.

FIG. **1** illustrates an example system, in accordance with embodiments of the disclosure.

FIGS. **2**A-B depict an example beauty products module using two-dimensional images to identify search parameters for a search of false eyelashes, in accordance with embodiments of the disclosure.

FIG. **3**A depicts an example database of false eyelashes, in accordance with embodiments of the disclosure.

FIGS. **3**B-C depict example false eyelash notifications, in accordance with embodiments of the disclosure.

FIG. **4** depicts a flow diagram of an example method for using two-dimensional images to identify search parameters for a search of false eyelashes, in accordance with embodiments of the disclosure.

FIG. **5**A illustrates an example human face that can be represented by image data, in accordance with embodiments of the disclosure.

FIG. **5**B represents an example eye area of an example human face that can be represented by image data, in accordance with embodiments of the disclosure.

FIG. **6** is an illustration of an exemplary artificial lash extension with a textured base, in accordance with embodiments of the disclosure.

FIG. **7** is an illustration of another exemplary artificial lash extension with a textured base, in accordance with embodiments of the disclosure.

FIG. **8** depicts an arrangement of artificial lash extensions in accordance with lash configuration information, in accordance with embodiments of the disclosure.

FIG. **9** is an example training set generator to create training data for a machine learning model using information pertaining to various beauty targets, in accordance with embodiments of the disclosure.

FIG. **10** is an example training set generator to create training data for a machine learning model using information pertaining to various beauty targets, in accordance with embodiments of the disclosure.

FIG. **11** is a block diagram of an example conversion system architecture for providing conversion of two-dimensional (2D) image data corresponding to a 2D image to a corresponding three-dimensional (3D) model, in accordance with embodiments of the disclosure.

FIG. **12** depicts an example 3D model of the face of a subject, in accordance with embodiments of the disclosure.

FIG. **13**A is an example pipeline block diagram for a principal component analysis (PCA) model generation architecture to train a PCA model of principal components, in accordance with embodiments of the disclosure.

FIG. **13**B is an example pipeline block diagram for generating a 3D model from 2D image data using a trained PCA model and a morphological model, in accordance with embodiments of the disclosure.

FIG. **14**A illustrates a flow diagram of an example method for training a PCA model, in accordance with embodiments of the disclosure.

FIG. **14**B illustrates a flow diagram of an example method for using a trained PCA model, in accordance with embodiments of the disclosure.

FIG. **15** is a block diagram illustrating an exemplary computer system in accordance with embodiments of the disclosure.

DETAILED DESCRIPTION

Embodiments described herein are related to methods and systems for using 2D images to identify search parameters for a search of artificial lash extensions.

Variation in human faces can be exceptionally high compared to many other body parts. This high degree of variability in facial features can be due to a combination of genetic, environmental, and stochastic factors. The human face exhibits a wide range of shapes, sizes, colors, and expressions, making each individual's face unique.

Beauty products are often developed to enhance or alter specific facial features, contributing to a relationship between facial variability and beauty products. For example, personal preference for facial features can vary widely among individuals. Beauty products can cater to individual preferences by offering a wide range of products for different purposes. In another example, as awareness of diverse beauty standards grows, the number of beauty products that are suitable for a wide range of facial features and that celebrate the natural variability in facial features also grows. With the high degree of variability in facial features, large number of personal preferences, and the large variety of beauty products, providing relevant information and services associated with beauty products can be challenging.

Some conventional systems may provide multiple beauty products for selection by a user. For example, a system may provide many varieties of false eyelashes for selection, each having different characteristics and each being applicable to different eye types and different styles. The system may provide descriptions and indications of the various characteristics to the user to aid the user in choosing false eyelashes or other beauty products. However, users may find it difficult to manually search and sort multiple beauty products and identify the appropriate beauty products to achieve a desired look while taking into account the user's unique facial features. Further, some conventional systems do not provide a visualization tool that allows the user to visualize how the beauty products may appear when applied to the user's unique facial features.

Embodiments of the disclosure address the above challenges as well as others by using image processing techniques on 2D images representing a user's face to generate information, such as 3D information identifying specific relationships between landmarks corresponding to unique facial features of the user's face, that can be used to improve and customize search parameters for a search query to search false eyelashes. Embodiments of the disclosure address the above challenges as well as others by using image processing techniques on 2D images representing a user's face to facilitate an augmented reality (AR) environment that can provide a geometrically accurate visualization of false eyelashes applied to the user's eye area.

In some embodiments, a beauty products platform can receive a 2D image taken by a camera and that represents a user's eye area (e.g., 2D image data representing the 2D image). The 2D image data can be transformed, using image processing techniques, from a 2D representation to a 3D structure (e.g., 3D model represented by 3D model data) that adds a third dimension (e.g., depth) to the information captured in the 2D image. The 3D model can have high dimensional accuracy (e.g., within ±2 millimeters (mm) of the dimensions of the actual object). 2D image data representing the 2D image of the user's eye area and/or 3D model data representing the 3D model of the user's eye area can be used to determine 2D relationships between facial features and/or 3D relationships between landmarks. A landmark can refer to a 3D representation of an object, such as a facial feature. The relationships can be determined using techniques such as identifying specific landmarks and calculating distances, ratios, or other metrics between them. For instance, specific relationships between the user's eye and eyebrow, such as a distance (e.g., dimensional data) between the user's eye and eyebrow can be determined (with high accuracy) using the 3D model.

Beauty products, and in particular false eyelashes, often are used to enhance or diminish particular facial features. By using geometric data (2D and/or 3D) of one or more particular facial features and/or relationship data (2D and/or 3D) between multiple facial features the dimensions of the user's facial features can be determined and used to select beauty products (e.g., false eyelashes) that enhance or diminish the dimensions of a user's unique facial features.

In some embodiments, the geometric data (2D and/or 3D) of one or more particular facial features and/or relationship data (2D and/or 3D) between multiple facial features can be used as parameters is a query to search for a subset of false eyelashes among multiple false eyelash, that are suitable for the user's unique facial features (e.g., suitable for the unique dimensions of the user's facial features). In some embodiments, the platform can perform the search using 2D/3D geometric data and/or 2D/3D relationship data derived from the 2D image of the user's eye area, as well as from preference data indicated by the user (e.g., a desired style, look or color). The platform can use the search parameters to perform a search to identify relevant false eyelashes and can present representations of the identified false eyelashes via a graphical user interface (GUI) displayed at the client device. For example, the platform can also present false eyelash configurations (e.g., style, length, color, position with respect to the eye) via the GUI.

In some embodiments, the beauty products platform can generate a 2D or 3D overlay of false eyelash products on a 3D model or 2D image of the user. For example, the beauty products platform can receive a selection of a false eyelash and incorporate a 3D model of the false eyelash into the 3D model of the user's eye area (e.g., perform a simulated application of the false eyelash to the user's eye area). The beauty products platform can generate a 2D rendering of the 3D model with the false eyelash applied.

As noted, a technical problem addressed by some embodiments of the disclosure is a lack of image processing techniques for determining image-based search parameters for searching false eyelashes or other beauty products and/or for providing an augmented reality (AR) environment for false eyelashes and other beauty products.

A technical solution to the above identified technical problem can include using image processing techniques to identify relationships between facial features and search multiple false eyelashes or other beauty products using the identified relationships and characteristics of the beauty products. In some embodiments, the image processing techniques can include converting 2D image data to 3D model data. Image processing techniques can further include identifying 2D facial features and/or 3D landmarks and determining relationships between sets of facial features or sets of landmarks. In some embodiments, the image processing techniques can be used to provide an AR environment that provides an accurate placement of a digital false eyelash or other beauty product as an overly on a subject's face.

Thus, the technical effect can include improved image processing techniques that can be used for generating enhanced search parameters for searching beauty products, and in particular identifying a subset of relevant beauty products by using image processing techniques to determine facial feature relationships that can be used to select relevant characteristics of beauty products. In some embodiments, the technical effect can include enhanced image processing techniques for use in AR environments.

A beauty product can refer to any substance or item designed for use on the body, particularly the face, skin, hair, and nails, often with the purpose of enhancing and/or maintaining beauty and appearance.

A facial feature can refer to a physical characteristic or element that is part of a human face. Facial features can include, but are not limited to the lips, nose, tip of the nose, bridge of the nose, eyes, inner eye, pupil, eyelids, eyebrows, inner eyebrow, outer eyebrow, center eyebrow, cheeks (e.g., check bones, etc.), jaw (e.g., jawline, etc.), among others.

FIG. **1** illustrates an example of a system **100**, in accordance with embodiments of the disclosure. The system **100** includes a beauty products platform **120**, one or more server machines **130-150**, a data store **106**, and client device **110** connected to network **104**. In some embodiments, system **100** can include one or more other platforms (such as those illustrated in FIGS. **2**A-B).

As noted above, a beauty product can refer to any substance or item designed for use on the body, particularly the face, skin, hair, and nails, often with the purpose of enhancing and/or maintaining beauty and appearance. Beauty products can often be part of personal care and grooming routines, and can serve various functions, such as cleansing, moisturizing, styling, and embellishing. Beauty products include, but are not limited to, skincare products such as cleansers, moisturizers, serums, toners, or other products designed to care for the skin and/or address specific skin concerns. Beauty products can include haircare product, such as shampoos, conditioners, hair masks, styling products, and treatments often designed to clean, nourish, and/or style the hair. Beauty products can include cosmetics, such as foundation, lipstick, eyeshadow, mascara, eyeliner, bronzer, or other items often applied to enhance facial features and/or create different "looks." Beauty products can include nail care products, such as nail polish, nail polish remover and/or other products that can help maintain healthy and/or attractive nails. Beauty products can include fragrance products such as perfumes and colognes designed to add or enhance the scent of the body or user. Beauty products can include personal care products such as deodorants, body lotions, shower gels, or other products designed to maintain personal hygiene. Beauty products can include false eyelashes, such as strip lashes, individual clusters, individual hairs, or artificial lash extensions that are designed for application at the eye area often to enhance or accentuate a user's eyes or eyelashes. Beauty products can include artificial nails, such as acrylic nails, gel nails, press-on nails, fiberglass or silk wraps, nail tips, semi-cured artificial nails and other products that are designed to protect and/or enhance a user's nails. Beauty products can include eyebrow products such as eyebrow pencils or pens, eyebrow powders, eyebrow gels, eyebrow pomades, eyebrow waxes, eyebrow highlighters, eyebrow stencils, eyebrow brushes or combs or other products that are designed to enhance and/or shape the eyebrows. Beauty products can include tools and accessories such as brushes, combs, sponges, applicators and/or other tools used in the application of various beauty products.

In some embodiments, network **104** can include a public network (e.g., the Internet), a private network (e.g., a local area network (LAN) or wide area network (WAN)), a wired network (e.g., Ethernet network), a wireless network (e.g., an 802.11 network or a wireless fidelity (Wi-Fi) network), a cellular network (e.g., a Long Term Evolution (LTE) network), routers, hubs, switches, server computers, and/or a combination thereof.

Data store **106** can be a persistent storage that is capable of storing data such as beauty products information, 2D image information, 3D model information, machine learning model data, etc. Data store **106** can be hosted by one or more storage devices, such as main memory, magnetic or optical storage based disks, tapes or hard drives, network-attached storage (NAS), storage area network (SAN), and so forth. In some embodiments, data store **106** can be a network-attached file server, while in other embodiments the data store **106** can be another type of persistent storage such as an object-oriented database, a relational database, and so forth, that can be hosted by beauty products platform **120**, or one or more different machines coupled to the server hosting the beauty products platform **120** via the network **104**. In some embodiments, data store **106** can be capable of storing one or more data items, as well as data structures to tag, organize, and index the data items. A data item can include various types of data including structured data, unstructured data, vectorized data, etc., or types of digital files, including text data, audio data, image data, video data, multimedia, interactive media, data objects, and/or any suitable type of digital resource, among other types of data. An example of a data item can include a file, database record, database entry, programming code or document, among others.

In some embodiments, data store **106** can implement beauty products database **125**. In some embodiments, beauty products database **125** can store information (e.g., data items) related to one or more beauty products.

In some embodiments, beauty products database **125** can include a vector database. In some embodiment, a vector database can index and/or store vector data, such as vector embeddings (e.g., also referred to as vector embedding data). In some embodiments, the vector embedding data can have the same or variable dimensionality. The vector embedding data can include one or more of word embedding data (e.g., vector representation of a word), image embedding data (e.g., vector representation of an image), audio embedding data (e.g., vector representation of audio content), and so forth. In some embodiments, the vector embedding data can represent one or more beauty products. Additional details of beauty products database **125** are further described herein.

The client device(s) (e.g., client device **110**) may each include a type of computing device such as a desktop personal computer (PCs), laptop computer, mobile phone, tablet computer, netbook computer, wearable device (e.g., smart watch, smart glasses, etc.) network-connected television, smart appliance (e.g., video doorbell), any type of mobile device, etc. In some embodiments, client devices **110** can be one or more computing devices (such as a rackmount server, a router computer, a server computer, a personal computer, a mainframe computer, a laptop computer, a tablet computer, a desktop computer, etc.), data stores (e.g., hard disks, memories, databases), networks, software components, or hardware components. In some embodiments, client device(s) may also be referred to as a "user device" herein. Although a single client device **110** is shown for purposes of illustration rather than limitation, one or more client devices can be implemented in some embodiments. Client device **110** will be referred to as client device **110** or client devices **110** interchangeably herein.

In some embodiments, a client device, such as client device **110**, can implement or include one or more applications, such as application **119** executed at client device **110**. In some embodiments, application **119** can be used to communicate (e.g., send and receive information) with beauty products platform **120**. In some embodiments, application **119** can implement user interfaces (UIs) (e.g., graphical user interfaces (GUIs)), such as a user interface (UI) (e.g., UI **112**) that may be webpages rendered by a web browser and displayed on the client device **110** in a web browser window. In another embodiment, the UIs **112** of client application, such as application **119** may be included in a stand-alone application downloaded to the client device **110** and natively running on the client device **110** (also referred to as a "native application" or "native client application" herein). In some embodiments, beauty products module **151** can be implemented as part of application **119**. In other embodiments, beauty products module **151** can be separate from application **119** and application **119** can interface with beauty products module **151**.

In some embodiments, one or more client devices **110** can be connected to the system **100**. In some embodiments, client devices, under direction of the beauty products platform **120** when connected, can present (e.g., display) a UI **112** to a user of a respective client device through application **119**. The client devices **110** may also collect input from users through input features.

In some embodiments, a UI **112** may include various visual elements (e.g., UI elements) and regions, and can be a mechanism by which the user engages with the beauty products platform **120**, and system **100** at large. In some embodiments, the UI **112** of a client device **110** can include multiple visual elements and regions that enable presentation of information, for decision-making, content delivery, etc. at a client device **110**. In some embodiments, the UI **112** may sometimes be referred to as a graphical user interface (GUI)).

In some embodiments, the UI **112** and/or client device **110** can include input features to intake information from a client device **110**. In one or more examples, a user of client device **110** can provide input data (e.g., a user query, control commands, etc.) into an input feature of the UI **112** or client device **110**, for transmission to the beauty products platform **120**, and system **100**A at large. Input features of UI **112** and/or client device **110** can include space, regions, or elements of the UI **112** that accept user inputs. For example, input features may include visual elements (e.g., GUI elements) such as buttons, text-entry spaces, selection lists, drop-down lists, etc. For example, in some embodiments, input features may include a chat box which a user of client device **110** can use to input textual data (e.g., a user query). The application **119** via client device **110** can then transmit that textual data to beauty products platform **120**, and the system **100** at large, for further processing. In other examples, input features can include a selection list, in which a user of client device **110** can input selection data e.g., by selecting, or clicking. The application **119** via client device **110** can then transmit that selection data to beauty products platform **120**, and the system **100** at large, for further processing.

In some embodiments, client device **110** can include a camera (e.g., digital camera) to capture images, such as two-dimensional (2D) images, and video (e.g., sequential video frames of a video item). The images and/or video can be sent to beauty products platform **120** using application **119**. In some embodiments, client device **110** can stream a video item to beauty products platform **120** using application **119**. The video frames of a video item can be arranged (e.g., sequentially arranged) using timestamps. In some embodiments, application **119** can be used to implement augmented reality (AR) or virtual reality (VR) features at client device **110**.

In some embodiments, a client device **110** can access the beauty products platform **120** through network **104** using one or more application programming interface (API) calls via platform API endpoint **121**. In some embodiments, beauty products platform **120** can include multiple platform API endpoints **121** that can expose services, functionality, or information of the beauty products platform **120** to one or more client devices **110**. In some embodiments, a platform API endpoint **121** can be one end of a communication channel, where the other end can be another system, such as a client device **110** associated with a user account. In some embodiments, the platform API endpoint **121** can include or be accessed using a resource locator, such a universal resource identifier (URI), universal resource locator (URL), of a server or service. The platform API endpoint **121** can receive requests from other systems, and in some cases, return a response with information responsive to the request. In some embodiments, HTTP (Hypertext Transfer Protocol), HTTPS (Hypertext Transfer Protocol Secure) methods (e.g., API calls) can be used to communicate to and from the platform API endpoint **121**.

In some embodiments, the platform API endpoint **121** can function as a computer interface through which access requests are received and/or created. In some embodiments, the platform API endpoint **121** can include a platform API whereby external entities or systems can request access to services and/or information provided by the beauty products platform **120**. The platform API can be used to programmatically obtain services and/or information associated with a request for services and/or information.

In some embodiments, the API of the platform API endpoint **121** can be any suitable type of API such as a REST (Representational State Transfer) API, a GraphQL API, a SOAP (Simple Object Access Protocol) API, and/or any suitable type of API. In some embodiments, the beauty products platform **120** can expose through the API, a set of API resources which when addressed can be used for requesting different actions, inspecting state or data, and/or otherwise interacting with the beauty products platform **120**. In some embodiments, a REST API and/or another type of API can work according to an application layer request and response model. An application layer request and response model can use HTTP, HTTPS, SPDY, or any suitable application layer protocol. Herein HTTP-based protocol is described for purposes of illustration, rather than limitation. The disclosure should not be interpreted as being limited to the HTTP protocol. HTTP requests (or any suitable request communication) to the beauty products platform **120** can observe the principals of a RESTful design or the protocol of the type of API. RESTful is understood in this document to describe a Representational State Transfer architecture. The RESTful HTTP requests can be stateless, thus each message communicated contains all necessary information for processing the request and generating a response. The platform API can include various resources, which act as endpoints that can specify requested information or requesting particular actions. The resources can be expressed as URI's or resource paths. The RESTful API resources can additionally be responsive to different types of HTTP methods such as GET, PUT, POST and/or DELETE.

It can be appreciated that in some embodiments, any element, such as server machine **130**, server machine **140**, server machine **150**, and/or data store **106** may include a corresponding API endpoint for communicating with APIs.

In some embodiments, the beauty products platform **120** may include one or more computing devices (such as a rackmount server, a router computer, a server computer, a personal computer, a mainframe computer, a laptop computer, a tablet computer, a desktop computer, etc.), data stores (e.g., hard disks, memories, databases), networks, software components, or hardware components that can be used to provide a user with access to data or services. Such computing devices can be positioned in a single location or can be distributed among many different geographical locations. For example, beauty products platform **120** can include multiple computing devices that together may comprise a hosted computing resource, a grid computing resource, or any other distributed computing arrangement. In some embodiments, beauty products platform **120** can correspond to an elastic computing resource where the allotted capacity of processing, network, storage, or other computing-related resources may vary over time.

In some embodiments, beauty products platform **120** can implement beauty products module **151**. In some embodiments, beauty products module **151** can implement one or more features and/or operations as described herein. In some embodiments, beauty products module **151** can include or access one or more of model **160**, and model output **165**. In some embodiments, beauty products platform **120** can receive 2D image data of a 2D image representing a human face of a subject and/or 3D model data of a 3D model representing the human face of the subject. Beauty products platform **120** can provide the 2D image data and/or the 3D model data to the beauty products module **151**. In some embodiments, beauty products module **151** can use the 2D image data and/or the 3D model data as an input to a trained machine learning model, such as model **160**. Model **160** can generate outputs, including model output **165**. The model output **165** can include information such as one or more of: (i) information identifying 2D facial features data represented in the 2D image data, (ii) information identifying 2D geometric data for respective 2D facial features, (iii) information identifying relationships between the 2D facial features represented in the 2D image data (e.g., 2D facial feature relationship data), (iv) information identifying 3D landmarks corresponding to the facial features (e.g., 3D landmark data), (v) information identifying 3D geometric data pertaining to the 3D landmark data corresponding to the 2D facial features, (vi) information identifying relationships between the 3D landmarks (e.g., 3D landmark relationship data), and/or (vii) information identifying variation information.

In some embodiments, beauty products platform **120** and in particular, the UI control module **124** may perform user-display functionalities of the system such as generating, modifying, and monitoring the client-side UIs (e.g., graphical user interfaces (GUI)) and associated components that are presented to users of the beauty products platform **120** through UI **112** client devices **110**. For example, beauty products module **151** via UI control module **124** can generate the UIs (e.g., UI **112** of client device **110**) that users interact with while engaging with the beauty products platform **120**.

In some embodiments, a machine learning model (e.g., also referred to as an "artificial intelligence (AI) model" herein) can include a discriminative machine learning model (also referred to as "discriminative AI model" herein), a generative machine learning model (also referred to as "generative AI model" herein), and/or other machine learning model.

In some embodiments, a discriminative machine learning model can model a conditional probability of an output for given input(s), A discriminative machine learning model can learn the boundaries between different classes of data to make predictions on new data. In some embodiments, a discriminative machine learning model can include a classification model that is designed for classification tasks, such as learning decision boundaries between different classes of data and classifying input data into a particular classification. Examples of discriminative machine learning models include, but are not limited to, support vector machines (SVM) and neural networks.

In some embodiments, a generative machine learning model learns how the input training data is generated and can generate new data (e.g., original data). A generative machine learning model can model the probability distribution (e.g., joint probability distribution) of a dataset and generate new samples that often resemble the training data. Generative machine learning models can be used for tasks involving image generation, text generation and/or data synthesis. Generative machine learning models include, but are not limited to, gaussian mixture models (GMMs), variational autoencoders (VAEs), generative adversarial networks (GANs), large language models (LLMs), visual language models (VLMs), multi-modal models (e.g., text, images, video, audio, depth, physiological signals, etc.), and so forth.

Training of and inference using discriminative machine learning models and generative machine learning models is described herein. It should be noted that although the training of and inference using discriminative machine learning model and generative machine learning model are described separately for the purposes of clarity, it can be appreciated that elements described with respect to discriminative machine learning models can apply to generative machine learning models, and vice versa, unless otherwise described.

In some embodiments, some elements of FIG. **1**, such as training set generator **131** of server machine **130**, training engine **141** of server machine **140**, and model **160** can apply to a discriminative machine learning model, unless otherwise described.

Server machine **130** includes a training set generator **131** that is capable of generating training data (e.g., a set of training inputs and a set of target outputs) to train a model **160** (e.g., a discriminative machine learning model). In some embodiments, training set generator **131** can generate the training data based on various data (e.g., stored at data store **106** or another data store connected to system **100**A via the network **104**). Data store **106** can store metadata associated with the training data.

Server machine **140** includes a training engine **141** that is capable of training a model **160** using the training data from training set generator **131**. The model **160** (also referred to "machine learning model" or "artificial intelligence (AI) model" herein) may refer to the model artifact that is created by the training engine **141** using the training data that includes training inputs (e.g., features) and corresponding target outputs (correct answers for respective training inputs) (e.g., labels). The training engine **141** may find patterns in the training data that map the training input to the target output (the answer to be predicted) and provide the model **160** that captures these patterns. The model **160** may be composed of, e.g., a single level of linear or non-linear operations (e.g., a support vector machine (SVM), or may be a deep network, i.e., a machine learning model that is composed of multiple levels of non-linear operations). An example of a deep network is a neural network with one or more hidden layers, and such machine learning model may be trained by, for example, adjusting weights of a neural network in accordance with a backpropagation learning algorithm or the like. Model **160** can use one or more of a support vector machine (SVM), Radial Basis Function (RBF), clustering, supervised machine learning, semi-supervised machine learning, unsupervised machine learning, k-nearest neighbor algorithm (k-NN), linear regression, random forest, neural network (e.g., artificial neural network), a boosted decision forest, etc. For convenience rather than limitation, the remainder of this disclosure describing discriminative machine learning model will refer to the implementation as a neural network, even though some implementations might employ other type of learning machine instead of, or in addition to, a neural network.

In some embodiments, such as with a supervised machine learning model, the one or more training inputs of the set of the training inputs are paired with respective one or more training outputs of the set of training outputs. The training input-output pair(s) can be used as input to the machine learning model to help train the machine learning model to determine, for example, patterns in the data.

In some embodiments, training data, such as training input and/or training output, and/or input data to a trained machine learning model (collectively referred to as "machine learning model data" herein) can be preprocessed before providing the aforementioned data to the (trained or untrained) machine learning model (e.g., discriminative machine learning model and/or generative machine learning model) for execution. Preprocessing as applied to machine learning models (e.g., discriminative machine learning model and/or generative machine learning model) can refer to the preparation and/or transformation of machine learning model data.

In some embodiments, preprocessing can include data scaling. Data scaling can include a process of transforming numerical features in raw machine learning model data such that the preprocessed machine learning model data has a similar scale or range. For example, Min-Max scaling (Normalization) and/or Z-score normalization (Standardization) can be used to scale the raw machine learning model. For instance, if the raw machine learning model data includes feature representing temperatures in Fahrenheit, the raw machine learning model data can be scaled to a range of [0, 1] using Min-Max scaling.

In some embodiments, preprocessing can include data encoding. Encoding data can include a process of converting categorical or text data into a numerical format on which a machine learning model can efficiently execute. Categorical data (e.g., qualitative data) can refer to a type of data that represents categories and can be used to group items or observations into distinct, non-numeric classes or levels. Categorical data can describe qualities or characteristics that can be divided into distinct categories, but often does not have a natural numerical meaning. For example, colors such as red, green, and blue can be considered categorical data (e.g., nominal categorical data with no inherent ranking). In another example, "small," "medium," and "large" can be considered categorical data (ordinal categorical data with an inherent ranking or order). An example of encoding can include encoding a size feature with categories ["small," "medium," "large"] by assigning 0 to "small," 1 to "medium," and 2 to "large."

In some embodiments, preprocessing can include data embedding. Data embedding can include an operation of representing original data in a different space, often of reduced dimensionality (e.g., dimensionality reduction), while preserving relevant information and patterns of the original data (e.g., lower-dimensional representation of higher-dimensional data). The data embedding operation can transform the original data so that the embedding data retains relevant characteristics of the original data and is more amenable for analysis and processing by machine learning models. In some embodiments embedding data can represent original data (e.g., word, phrase, document, or entity) as a vector in vector space, such as continuous vector space. Each element (e.g., dimension) of the vector can correspond to a feature or property of the original data (e.g., object). In some embodiments, the size of the embedding vector (e.g., embedding dimension) can be adjusted during model training. In some embodiments, the embedding dimension can be fixed to help facilitate analysis and processing of data by machine learning models.

In some embodiments, the training set is obtained from server machine **130**. Server machine **150** includes a beauty products module **151** that provides current data (e.g., 2D image data, etc.) as input to the trained machine learning model (e.g., model **160**) and runs the trained machine learning model (e.g., model **160**) on the input to obtain one or more outputs.

In some embodiments, confidence data can include or indicate a level of confidence of that a particular output (e.g., output(s)) corresponds to one or more inputs of the machine learning model (e.g., trained machine learning model). In one example, the level of confidence is a real number between 0 and 1 inclusive, where 0 indicates no confidence that output(s) corresponds to a particular one or more inputs and 1 indicates absolute confidence that the output(s) corresponds to a particular one or more inputs. In some embodiments, confidence data can be associated with inference using a machine learning model.

In some embodiments, machine learning model, such as model **160**, may be (or may correspond to) one or more computer programs executed by processor(s) of server machine **140** and/or server machine **150**. In other embodiments, machine learning model may be (or may correspond to) one or more computer programs executed across a number or combination of server machines. For example, in some embodiments, machine learning models may be hosted on the cloud, while in other embodiments, these machine learning models may be hosted and perform operations using the hardware of a client device **110**. In some embodiments, the machine learning models may be a self-hosted machine learning model, while in other embodiments, machine learning models may be external machine learning models accessed by an API.

In some embodiments, server machines **130** through **150** can be one or more computing devices (such as a rackmount server, a router computer, a server computer, a personal computer, a mainframe computer, a laptop computer, a tablet computer, a desktop computer, etc.), data stores (e.g., hard disks, memories, databases), networks, software components, or hardware components that can be used to provide a user with access to one or more data items of the beauty products platform **120**. The beauty products platform **120** can also include a website (e.g., a webpage) or application back-end software that can be used to provide users with access to the beauty products platform **120**.

In some embodiments, one or more of server machine **130**, server machine **140**, model **160**, server machine **150** can be part of beauty products platform **120**. In other embodiments, one or more of server machine **130**, server machine **140**, server machine **150**, or model **160** can be separate from beauty products platform **120** (e.g., provided by a third-party service provider).

Also as noted above, for purpose of illustration, rather than limitation, embodiments of the disclosure describe the training of a machine learning model (e.g., model **160**) and use of a trained machine learning model (e.g., model **160**). In other embodiments, a heuristic model or rule-based model can be used as an alternative. It should be noted that in some other embodiments, one or more of the functions of beauty products platform **120** can be provided by a greater number of machines. In addition, the functionality attributed to a particular component of the beauty products platform **120** can be performed by different or multiple components operating together. Although embodiments of the disclosure are discussed in terms of beauty products platforms, embodiments can also be generally applied to any type of platform or service.

FIG. **2**A is an example system **200** for using 2D image data enhanced by image processing techniques to perform a search, such as a search of false eyelashes, in accordance with embodiments of the disclosure. System **200** includes data store **106**, client device **110**, and beauty products module **151**, which may correspond to respective components of FIG. **1**. Input data **202** can be provided to beauty products module **151** by client device **110**, and output data **250** can be provided to client device **110** by the beauty products platform **120**, such as by beauty products module **151**. Beauty products module **151** can use input data **202** to generate a 3D model of a user's face and/or eye area and determine relationships between 3D landmarks on the model. The relationship data can be used, in combination with user preferences, to generate search parameters and search a false eyelash database. In some embodiments, system **200** can include more or fewer components than those depicted in FIG. **2**A.

In some embodiments, input data **202** can include one or more of 2D image data **204** and user preference data **206**. In some embodiments, beauty products module **151** can receive some or all of input data **202** from client device **110** or from other sources, such as data store **106**. In some embodiments, client device **110** can generate or obtain input data **202**. For example, client device **110** can cause an imaging device coupled to client device **110**, such as a camera, to capture a 2D image represented by 2D image data **204**. In another example, client device **110** can retrieve 2D image data **204** from a memory location, such as from data store **106**. As previously described, 2D image data **204** can be 2D image data of a 2D image representing a human face of a subject or regions thereof. For example, 2D image data **204** can correspond to a 2D image of an eye area of a subject. In some embodiments, the 2D image data **204** can represent a frontal facial image of the subject. 2D image data **204** can be used (e.g., through various image processing techniques) to search or filter beauty products based on facial features or landmarks of the face (e.g., of the eye area), as described herein. 2D image data **204** can represent one or more 2D video images (e.g., frames) of a video stream or other types of 2D images. 2D image data **204** may correspond to image **1102** of FIG. **11**.

In some embodiments, user preference data **206** can identify user preferences of a subject, which can be used to search or filter beauty products. For example, user preference data **206** can identify one or more of a color preference, a style preference, length preference, or any other preference. In some embodiments, user preference data **206** indicates user preference information that may not be identified from 2D image data. In some embodiments, user preference data **206** can be obtained from a user of client device **110**. For example, user preference data **206** can be received by presenting the user with a predetermined, selectable list (e.g., in a user interface of application **119**). In another example, user preference data **206** can be received as a free-response from the user of client device **110** (e.g., a text or other input into a free-response field). In another example, user preference data **206** can be received as a multi-modal input from the user of client device **110**. A multimodal input field can include a field capable of accepting two or more different input modalities, such as two or more of a text input, an image input, an audio input, a video input, etc., from a user of client device **110**.

In some embodiments, input data can include other types of input data, such as user/account data, calendar/event data, facial feature type data, metadata, additional 2D or 3D data, other types of data described herein, or other data that may be relevant to beauty products module **151** (e.g., for searching or filtering beauty products). In some embodiments, 2D image data **204** or user preference data **206** may be absent from input data **202**.

In some embodiments, beauty products module **151** includes one or more of conversion system **210**, relationship module **220**, and search module **240**. In some embodiments, 3D model **212** can be provided to relationship module **220** by conversion system **210**, and relationship output **230** can be provided to search module **240** by relationship module **220**. In some embodiments, beauty products module **151** can include more or fewer components than those depicted in FIG. **2**A. For example, beauty products module **151** can additionally include modules depicted in FIG. **2**B. In another example, components depicted in FIG. **2**A as being included in beauty products module **151** may alternatively be included in client device **110** (e.g., conversion system **210**).

In some embodiments, 3D model **212** can include 3D model data **214**. In some embodiments, 3D model data **214** can represent a three-dimensional digital representation of a scene or object (e.g., a 3D model). In some embodiments, 3D model data **214** of 3D model **212** can include width information, height information, and depth information of the scene and/or object. 3D model data **214** can include geometric data that describes the corresponding scene or object. The geometric data can include one or more of vertices (e.g., points), edges, and/or faces. In some embodiments, vertices (e.g., nodes or points) can include points of a 3D model. A vertex can have 3D coordinates (e.g., x-, y-, and z-coordinates). The vertex can identify a location where one or more edges intersect. In some embodiments, an edge can include a line, such as a straight line and connect at least two vertices. In some embodiments, faces can include surfaces, such as planar surfaces, connecting edges (e.g., closed-loop edges). In some embodiments, one or more of vertices, edges and faces can define the geometry of 3D model **212**.

In some embodiments, 3D model data **214** of 3D model **212** can include texture information that describes an object's surface texture. In some embodiments, 3D model data **214** does not include texture information. In some embodiments, 3D model data **214** includes material information that can influence the appearance of 3D model **212** at rendering (e.g., how light reflects from the material). In some embodiments, 3D model data **214** does not include material information. In some embodiments, 3D model data **214** includes lighting information that describes the interaction of light (and absence of light) with the scene or object. In some embodiments, 3D model data **214** does not include lighting information. In some embodiments, 3D model data **214** includes color information that indicates the colors of surface (e.g., faces) of 3D model **212**.

In some embodiments, 3D model data **214** of 3D model **212** can include landmark data, such as 3D landmark data **216** (also referred to as "landmark data" herein). In some embodiments, one or more landmarks can be represented by 3D landmark data **216**. A landmark can refer to a specific point or a specific grouping of points of a 3D model **212**. A landmark can represent or correspond to one or more features, such as one or more facial features of a subject's face. The one or more features, such as facial features can be represented in 3D model **212** by the specific point or specific grouping of points. For example, a landmark can correspond to or represent the right eye, the inner corner of the eyes, the bridge of the nose, a center line of a face, and so forth. The landmark can be represented by the grouping of points of 3D model **212** that represent the right eye, the inner corner of the eyes, the bridge of the nose, a center line of a face, or some other facial feature. In some embodiments, a landmark can include relationships between one or more points (e.g., edges, faces, geometric data, such as length, height, and depth, and/or ratios of geometric data). For instance, the landmark can include a distance between the inner corner of the right eye and the outer corner of the right eye. In some embodiments, a landmark can include a combination of facial features and/or relationships between multiple facial features.

In some embodiments, 3D landmark data **216** can include information identifying one or more points of 3D model **212** (e.g., specific grouping of points and/or 3D coordinate data of the points) that correspond to a feature, such as a facial feature. In some embodiments, 3D landmark data **216** can include information identifying the relationship between one or more points of a landmark. To identify the relationship between the one or more points of a landmark, 3D landmark data **216** can include information identifying one or more of edges, faces, geometric data, such as length, height, and depth, and/or ratios of geometric data. To identify the relationship between the one or more points of a landmark, 3D landmark data **216** can include one or more of absolute or relative values (e.g., deviations from average or template values). In some embodiments, 3D landmark data **216** can include information identifying relationships between multiple landmarks. 3D landmark data **216** that identifies relationships between multiple landmarks can identify one or more of edges, faces, geometric data, such as length, height, and depth, ratios of geometric data, and/or absolute or relative values (e.g., deviations from average or template values). For instance, a ratio between the length of the eyebrow and the distance between the eyebrow and a point on the eye can be included on 3D landmark data **216**. In some embodiments, 3D model data **214** and/or 3D landmark data **216** can further include 2D and/or 3D geometric data, as described with reference to FIG. **9**.

In some embodiments, conversion system **210** converts 2D image data to a corresponding 3D model. For example, conversion system **210** can convert 2D image data representing a human face or and eye area of a face to a 3D model of the face or eye area of the face, respectively. The 2D image data input may be 2D image data **204**, and the 3D model output may be 3D model **212**. Conversion system **210** can use various image processing techniques to convert 2D image data to a 3D model, such as ML-based or non-ML-based techniques. An example technique for converting 2D image data to a 3D model using principal component analysis (PCA) is further described with reference to FIGS. **11-14**B. In some embodiments, conversion system **210** is, includes, or is included in model **160** of FIG. **1**. Model output **165** may correspond to 3D model **212**. In some embodiments, as described above, conversion system **210** may be included in client device **110** rather than beauty products module **151**. Input data **202** would thus include 3D model **212** in place of or in addition to 2D image data **204**.

Relationship output **230** includes 2D relationship data **232** and/or 3D relationship data **234**. In some embodiments, 2D relationship data **232** or 3D relationship data **234** may be absent from relationship output **230**. In some embodiments, relationship output **230** may include other types of relationship data.

In some embodiments, 2D relationship data **232** can include data identifying a relationship between two or more facial features (e.g., as present in 2D image data **204**, or as determined by relationship module **220**). In some embodiments, 2D relationship data **232** can include data identifying a relationship between 2D geometric data of two or more facial features. In some embodiments, the relationships between data corresponding to a first facial feature (e.g., first 2D facial feature data, and/or first 2D geometric data) and data corresponding to a second facial feature (e.g., second 2D facial feature data, and/or second 2D geometric data) can include one or more of distances between 2D points, angles, positions, or ratios of 2D information.

In some embodiments, 2D relationship data **232** can include data identifying a line or curve between one or more 2D points of a first facial feature and one or more 2D points of a second facial feature. For instance, 2D relationship data **232** can include data identifying a distance between one or more points representing the left eye and one or more points representing the right eye.

In some embodiments, 2D relationship data **232** can include data identifying a first line between two or more 2D points of a first facial feature and a second line between two or more 2D points of a second facial feature, and the angle between the first line and the second line. For instance, 2D relationship data **232** can include data identifying an angle between a horizontal line between 2D points representing the right and left pupils, and a right eye line between 2D points representing the inner corner of the right eye and the outer corner of the right eye.

In some embodiments, 2D relationship data **232** can include data identifying a first position corresponding to one or more 2D points of a first facial feature and a second position corresponding to one or more 2D points of a second facial feature, and a relationship between the first position and the second position (e.g., represented as x-, y-coordinate data). For instance, 2D relationship data **232** can include data identifying a relationship between a first x-, y-coordinate of one or more 2D points representing the nose, and a second x-, y-coordinate of one or more 2D points representing the mouth.

In some embodiments, 2D relationship data **232** can include data identifying a first size corresponding to one or more 2D points of a first facial feature and a second size corresponding to one or more 2D points of a second facial feature, and a ratio between the first size and the second size. For instance, 2D relationship data **232** can include data identifying a ratio between an eye size (represented by one or more 2D points representing the cye) and a mouth size (represented by one or more 2D points representing the mouth).

In some embodiments, 3D relationship data **234** can include data identifying a relationship between 3D landmark data corresponding to two or more respective facial features (e.g., 3D landmark data **216**). In some embodiments, 3D relationship data **234** can include data identifying a relationship between 3D geometric data corresponding to two or more facial features. In some embodiments, the relationships between data corresponding to a first facial feature and data corresponding to a second facial feature can include one or more of distances, angles, positions, or ratios.

In some embodiments, 3D relationship data **234** can include data identifying a line or curve between one or more 3D points corresponding to a first facial feature and one or more 3D points corresponding to a second facial feature. In some embodiments, one or more of the first facial feature or second facial feature can be represented in 3D landmark data **216**. For example, 3D relationship data **234** can include data identifying a 3D distance between one or more points representing the left eye and one or more points representing the right eye (e.g., the distance between the left and right eye).

In some embodiments, 3D relationship data **234** can include data identifying a first line between two or more 3D points of a first facial feature and a second line between two or more 3D points of a second facial feature, and an angle(s) (e.g., 3D angle) between the first line and the second line. For example, 3D relationship data **234** can include data identifying a 3D angle(s) between a horizontal plane that intersects the 3D points representing the right and left pupils, and a right eye line between 3D points representing the inner corner of the right eye and the outer corner of the right eye.

In some embodiments, 3D landmark relationship data **234** can include data identifying a first 3D position corresponding to one or more 3D points corresponding to a first facial feature and a second position corresponding to one or more 3D points of a second facial feature, and a relationship between the first 3D position and the 3D second position (e.g., represented as x-, y-, and z-coordinate position). For instance, 3D relationship data **234** can include data identifying a relationship between a first x-, y-, z-coordinate representing the nose, and a second x-, y-, z-coordinate representing the mouth.

In some embodiments, 3D relationship data **234** can include data identifying a first measurement (e.g., size, length, depth, width, area, etc.) corresponding to a first facial feature (corresponding to one or more 3D points) and a second measurement corresponding to a second facial feature (corresponding to one or more 3D points), and a ratio between the first measurement and the second measurement. For instance, 3D relationship data **234** can include data identifying a ratio between an eye size (represented by one or more 3D points representing the eye) and a mouth size (represented by one or more 3D points representing the mouth).

Additional details regarding 2D facial feature relationship data such as 2D relationship data **232** and 3D landmark relationship data such as 3D relationship data **234** are described below with reference to FIGS. **5**A-B.

In some embodiments, relationship module **220** determines 2D relationships between facial features and/or 3D relationships between 3D landmarks. For example, relationship module **220** may receive 2D image data **204** and/or 3D model **212** as inputs and provide 2D relationship data **232** and/or 3D relationship data **234** as outputs. Relationship module **220** can use various techniques for determining 2D and 3D relationships. In some embodiments, relationship module **220** includes logic-based relationships submodule **222** for using logic-based techniques to determine relationships. In some embodiments, relationship module **220** includes ML-based relationships submodule **224** for using ML-based techniques to determine relationships. An example system for determining relationships using ML techniques is further described with reference to FIGS. **9-10**. In some embodiments, relationships may be determined by other components of system **200** or system **100**. For example, 3D relationship data may be determined conversion system **210** during generation of 3D model **212**.

In some embodiments, logic-based relationships submodule **222** determines 2D and/or 3D relationships using one or more operations, algorithms, steps, or similar. In some embodiments, logic-based relationships submodule **222** identifies a set of facial features of a 2D image or a set of landmarks of a 3D model. For example, logic-based relationships submodule **222** may identify a pair of landmarks of 3D landmark data **216**, with a first landmark corresponding to, e.g., a pupil and a second landmark corresponding to, e.g., a midpoint of an eyebrow. In some embodiments, landmarks may be identified based on textual identifiers or characteristics provided by client device **110**, conversion system **210**, or other module. For example, conversion system **210** may provide textual identifiers for landmarks as part of the 2D-to-3D conversion process (e.g., points [a-n] and lines [a-n] represent an "right eye"). In some embodiments, the landmarks may be identified using ML textual identifiers. For example, ML-based relationships submodule **224** may provide textual identifiers which are used by logic-based relationships submodule **222** to identify the landmarks.

In some embodiments, logic-based relationships submodule **222** determines a distance, ratio, or other metric between facial features of a set of facial features or between landmarks of a set of landmarks. For example, after identifying a pair of landmarks as described above (e.g., a pupil and an eyebrow midpoint), logic-based relationships submodule **222** may perform one or more operations (e.g., subtraction) on the x-, y-, and z-coordinates of the landmarks (e.g., obtained from 3D model data **214**) to determine a distance between the landmarks. In another example, logic-based relationships submodule **222** may perform one or more operations (e.g., division) on a pair of distances between respective pairs of landmarks to determine a ratio between the landmarks. The determined distance, ratio, or other metric may be the determined relationship or may be part of the determined relationship (e.g., the relationship may include multiple distances, etc.).

In some embodiments, data store **106** includes false eyelash database **236**. False eyelash database **236** may include identifiers of one or more false eyelash products. As described with reference to FIGS. **6**-**7**, some false eyelash products, in some embodiments, can be designed or configured for application at the underside of the natural eyelashes of the user, or alternatively, even the top side of the natural eyelashes of a user. False eyelash database **236** can further or alternatively identify sets of false eyelashes in accordance with lash configuration information (e.g., sets of false eyelashes corresponding to respective lash configuration information), as described with reference to FIG. **8**. In some embodiments, data store **106** can further or alternatively include other beauty products databases, such as lipstick databases, eyeliner databases, combined databases, etc. False eyelash database **236** (or other beauty products databases of data store **106**) may identify beauty products of one or more beauty products entities (e.g., producers or suppliers). In some embodiments, false eyelash database **236** may identify characteristics associated with each of the false eyelashes within false eyelash database **236**. For example, false eyelash database **236** may identify one or more of a color characteristic, a length, characteristic, a style characteristic, a description characteristic, a price characteristic, or similar. Each false eyelash identified in false eyelash database **236** may correspond to a respective value (or range of values) for a given characteristic. For example, a particular false eyelash may have a length (e.g., characteristic) of 5 millimeters (mm) (e.g., value).

In some embodiments, output data **250** can be provided by beauty products module **151** to client device **110** or other recipient device or component. In some embodiments, output data **250** includes false eyelash notification **252**. False eyelash notification **252** can include an indication (e.g., identifier) of one or more false eyelashes (or other beauty products), such as identifiers of false eyelashes, images of false eyelashes, other types of media, or similar. In some embodiments, false eyelash notification **252** can be associated with a presentation of the indication to a user of client device **110**. For example, the indication of one or more false eyelashes may be presented to the user via UI **112**. Example false eyelash notifications are further described with respect to FIGS. **3**A-C.

In some embodiments, search module **240** can search or filter a beauty products database such as false eyelash database **236** to identify a subset of beauty products. For example, search module **240** may identify a subset of false eyelashes that may be of interest to the user based on various input data. In some embodiments, search module **240** may receive one or more of relationship output **230**, user preference data **206**, or other data as input data. Search module **240** can further include one or more search submodules, such as relationship-based search submodule **242** and user preference-based search submodule **244**, to search beauty products based on these various input data.

In some embodiments, relationship-based search submodule **242** identifies a subset of the false eyelashes of false eyelash database **236** based on relationship output **230**. In some embodiments, relationship-based search submodule **242** uses 2D relationship data **232** and/or 3D relationship data **234** to determine a range for a value of a characteristic of false eyelash database **236**. For example, the relationship data can indicate an appropriate length or range of lengths for false eyelashes based on the user's unique facial features. The determined range may be a continuous range (including a single value), a discrete range (including a single value), an enumerated range (e.g., a list of values), or other type of range. In some embodiments, relationship-based search submodule **242** uses the determined range(s) to identify, select, filter, etc. the subset of false eyelashes from false eyelash database **236**. For example, false eyelashes having values of characteristics within the determined range(s) may be identified as part of the subset.

In some embodiments, user preference-based search submodule **244** identifies a subset of the false eyelashes of false eyelash database **236** based on user preference data **206**. In some embodiments, user preference-based search submodule **244** uses user preference data **206** to determine a range for a value of a characteristic of false eyelash database **236**. For example, user preference data **206** can indicate a desired style or group of styles for false eyelashes based on the user's preferences. The determined range may be a continuous range (including a single value), a discrete range (including a single value), an enumerated range (e.g., a list of values), or other type of range. In some embodiments, user preference-based search submodule **244** uses the determined range(s) to identify, select, filter, etc. the subset of false eyelashes from false eyelash database **236**. For example, false eyelashes having values of characteristics within the determined range(s) may be identified as part of the subset.

In some embodiments, the subset of false eyelashes can be identified from a table or matrix. For example, a Structured Query Language (SQL) query including the determined range(s) can be used to identify the subset from a database table.

In some embodiments, relationship-based search submodule **242** identifies a subset of false eyelashes of an output of user preference-based search submodule **244**, or vice versa. For example, false eyelashes of false eyelash database **236** may be searched a first time by relationship-based search submodule **242**, and the search results (e.g., first subset of false eyelashes) may be searched a second time by user preference-based search submodule to determine the subset of false eyelashes (e.g., sub subset of false eyelashes) to be presented to the user via client device **110**. In some embodiments, relationship-based search submodule **242** and user preference-based search submodule **244** may be used together to determine the subset of false eyelashes of false eyelash database **236**.

In some embodiments, search module **240** can generate or provide an output that can be used to generate a false eyelash notification including false eyelash configurations, each including multiple false eyelashes. For example, relationship-based search submodule **242** and/or user preference-based search submodule **244** may identify false eyelash configurations of pluralities of false eyelashes that correspond to a determined relationship or to user preferences. False eyelash configurations are further described with reference to FIGS. **3**C and **8**.

FIG. **2**B is an example system **260** for using 2D image data to generate a 3D overlay of false eyelash products on a 3D model or 2D image of the user, in accordance with embodiments of the disclosure. System **260** includes one or more of data store **106**, client device **110**, and beauty products module **151**, which may correspond to respective components of FIG. **1**. Input data **262** can be provided to beauty products module **151** by client device **110**, and output data **280** can be provided to client device **110** by beauty products module **151**. Beauty products module **151** can use input data **262** to generate a 3D model of a user's face and/or eye area, or a 3D model generated in FIG. **2**A can be reused. The 3D model can be combined with models of false eyelashes to generate an augmented reality overlay demonstrating how the false eyelashes would look on the user's face. In some embodiments, system **260** can include more or fewer components than those depicted in FIG. **2**B.

In some embodiments, input data **262** includes one or more of 2D image data **204** and false eyelash selection **264**. In some embodiments, beauty products module **151** can receive some or all of input data **262** from client device **110** or from other sources, such as data store **106**. In some embodiments, client device **110** can generate or obtain input data **262**, as described with reference to FIG. **2**A.

In some embodiments, false eyelash selection **264** can identify one or more false eyelashes selected by a user of client device **110**. For example, the selected false eyelashes may be a subset of false eyelashes indicated in false eyelash notification **252** of FIG. **2**A. The false eyelashes of false notification **252** may be presented as a selectable list (e.g., in a user interface of application **119**), and a selection interaction of the user may be received to determine false eyelash selection **264**. In another example, the selected false eyelashes may be a subset of false eyelashes indicated in false eyelash database **236** (e.g., the user may select false eyelashes from the full catalog of false eyelashes).

In some embodiments, input data **262** can include other types of input data, such as user data, user account data, calendar data, (e.g., event data), facial feature type data, metadata, additional 2D or 3D data, other types of data described herein, or other data that may be relevant to beauty products module **151** (e.g., for searching or filtering beauty products). In some embodiments, 2D image data **204** or false eyelash selection **264** may be absent from input data **262**. For example, 2D model **212** may be reused from FIG. **2**A, and thus 2D image data **204** may not be needed for generating an augmented reality preview. In some embodiments, 2D image data **204** may be the same 2D image data in both FIGS. **2**A and **2**B. In some embodiments, 2D image data **204** may be different between FIGS. **2**A and **2**B (e.g., 2D image data **204** in FIG. **2**B may be a later frame of a video stream).

In some embodiments, beauty products module **151** can include conversion system **210** and augmented reality (AR) module **270**. 3D model **212** can be provided to AR module **270** by conversion system **210**. In some embodiments, conversion system **210** and 3D model **212** may conform to aspects described with reference to FIG. **2**A. In some embodiments, beauty products module **151** can include more or fewer components than those depicted in FIG. **2**B. For example, beauty products module **151** can additionally include modules depicted in FIG. **2**A. In another example, components depicted in FIG. **2**B as being included in beauty products module **151** may alternatively be included in client device **110** as described with reference to FIG. **2**A (e.g., conversion system **210**).

In some embodiments, AR module **270** includes AR false eyelash submodule **272** and rendering module **274**. In some embodiments, AR module **270** can generate a 3D overlay of false eyelash products on a 3D model or 2D image of the user. The 3D overlay may serve as a preview of what the false eyelash products may look like when applied to the user's eyelashes.

In some embodiments, AR false eyelash submodule **272** can receive an indication of one or more false eyelashes to overlay on a 3D model. The indication may correspond to false eyelash selection **264** or may originate from another source. AR false eyelash submodule **272** may obtain data of the corresponding false eyelashes from false eyelash database **236**. For example, AR false eyelash submodule **272** may obtain 3D models of the corresponding false eyelashes from false eyelash database **236**. AR false eyelash submodule **272** can further receive a 3D model of the user's face or eye area, such as 3D model **212** generated by conversion system **210**. AR false eyelash module **272** can overlay the false eyelashes on 3D model **212** by identifying landmarks (of 3D landmark data **216**) corresponding to the user's eyelashes and positioning, rotating, and/or scaling the 3D models of the false eyelashes to correspond to the location and orientation of the user's eyelashes. In some embodiments, AR false eyelash submodule **272** can adjust lighting and other characteristics of the overlaid 3D model to simulate an environment in which the user is wearing the false eyelashes (e.g., a dinner environment, a party environment, etc.). In some embodiments, AR false eyelash submodule **272** can simulate the user blinking or displaying various facial expressions and how these motions interact with the false eyelashes.

In some embodiments, rendering submodule **274** can receive an 3D model with false eyelash overlays from AR false eyelash submodule **272**. Rendering submodule **274** can render a projection of the overlaid 3D model and generate a 2D image representing the render. The 2D image may correspond to false eyelash media content **282** of output data **280**, which may be provided to client device **110** for presentation to the user. In some embodiments, rendering submodule **274** can generate an updated 2D image of the user's eye area corresponding to 2D image data **204**, with the selected false eyelashes applied. In some embodiments, rendering submodule **274** can render a projection indicated by the user (e.g., via input data **262**). For example, the user may indicate that a side projection is to be rendered to enable the user to preview how the selected false eyelashes will look from the side.

FIGS. **3**A-C depict example false eyelash notifications **320** (FIG. **3**B) and **330** (FIG. **3**C) with reference to example false eyelash database **236** (FIG. **3**A), in accordance with embodiments of the disclosure. In some embodiments, false eyelash database **236** of FIG. **3**A corresponds to false eyelash database **236** of FIGS. **2**A-B, and false eyelash notifications **320** and **330** of FIGS. **3**B-C correspond to false eyelash notification **252** of FIG. **2**A. Referring to FIG. **3**A, false eyelash database **236** includes one or more false eyelashes **310**A-N, as described with reference to FIG. **2**A and subsequent figures. False eyelash database **236** may be a structured or unstructured database, such as a SQL database including tables of false eyelash product identifiers and characteristics. False eyelash notifications **320** and **330** may include references to false eyelashes in false eyelash database **236** (e.g., record identifiers corresponding to rows in a SQL table) and/or data extracted from false eyelash database **236** (e.g., record values corresponding to rows in a SQL table).

Referring to FIG. **3**B, false eyelash notification **320** identifies one or more false eyelashes **322**A-N. In some embodiments, false eyelashes **322**A-N may be a subset (e.g., a proper subset) of false eyelashes **310**A-N identified in false eyelash database **236**. For example, each false eyelash of false eyelashes **322**A-N may correspond to a respective false eyelash of false eyelashes **310**A-N. In some embodiments, false eyelashes **322**A-N may be a subset of false eyelashes identified by search module **240** of FIG. **2**A.

Referring to FIG. **3**C, false eyelash configuration notification **330** includes one or more false eyelash configurations **332**A-N (e.g., as described with reference to FIG. **8**). Each false eyelash configuration of false eyelash configurations **332**A-N can identify one or more false eyelashes. For example, false eyelash configuration **332**A includes false eyelashes **334**A-N. In some embodiments, a false eyelash may be included in more than one false eyelash configuration. For example, false eyelash **334**A may be included in false eyelash configurations **332**A-B (not depicted). In some embodiments, false eyelash configuration **332**A is a lash configuration information, and false eyelashes **334**A-N are artificial lash extensions. Lash configuration information and artificial lash extensions are further described with reference to FIGS. **6**-**8**. In some embodiments, false eyelashes **334**A-N may be a subset (e.g., a proper subset) of false eyelashes **310**A-N. For example, each false eyelash of false eyelashes **334**A-N may correspond to a respective false eyelash of false eyelashes **310**A-N. In some embodiments, false eyelash configurations **332**A-N and their respective false eyelashes may be a subset of false eyelashes identified by search module **240** of FIG. **2**A.

FIG. **4** depicts a flow diagram of one example of a method **400** for using 2D images to identify search parameters for a search of false eyelashes, in accordance with embodiments of the disclosure. The method **400** is performed by processing logic that can include hardware (circuitry, dedicated logic, etc.), software (e.g., instructions run on a processing device), or a combination thereof. In one embodiment, some or all the operations of method **400** can be performed by one or more components of system **100**, system **200**, or system **260** of FIGS. **1** and **2**A-B, such as beauty products module **151**. It can be noted that components described with reference to FIGS. **1** and **2**A-B can be used to illustrate aspects of FIG. **4**. In some embodiments, the operations (e.g., operations **401**-**408**) can be the same, different, fewer, or greater. For example, operations indicated with a dashed outline (e.g., **404**, **406**-**408**) may be absent in some embodiments.

At operation **401**, processing logic implementing the method **400** receives 2D image data corresponding to a 2D image of an eye area of a subject. In some embodiments, the 2D image data can be 2D image data **204** of FIGS. **2**A-B, and the 2D image data can be received by beauty products module **151**.

In some embodiments, the processing logic further receives, among multiple lash styles, a user preference identifying a first lash style, wherein identifying, among the multiple false eyelashes, the subset of false eyelashes is based at least in part on the user selection identifying the first lash style. Other user preference data may be received in various embodiments.

At operation **402**, processing logic generates, using the 2D image data, a 3D model of the eye area. In some embodiments, the 3D model of the eye area can be 3D model **212**, which can be generated by conversion system **210** using the 2D image data. In some embodiments, generating the 3D model may include providing the 2D image data as input to conversion system **210** and obtaining one or more outputs of conversion system **210**, the one or more outputs corresponding to the 3D model.

At operation **403**, processing logic determines a relationship between a first landmark of the 3D model representing a first facial feature of the eye area and a second landmark of the 3D model representing a second facial feature of the eye area. In some embodiments, the first and second landmarks of the 3D model may be landmarks of 3D landmark data **216**, the relationship between the landmarks may be included in 3D relationship data **234**, and the relationship may be determined by relationship module **220**. In some embodiments, processing logic may determine a relationship (e.g., 2D relationship data **232**) between the first and second facial features (e.g., from 2D image data **204**) using relationship module **220**. In some embodiments, 2D information, such as one or more of 2D facial feature data, 2D geometric data, or 2D relationship date can be used in addition to or in lieu of 3D information.

In some embodiments, the relationship between the first and second landmarks may include a geometric relationship or another type of relationship described with reference to 3D relationship data **234**. In some embodiments, determining the relationship may include identifying the first landmark and the second landmark on the 3D model (e.g., as described with reference to logic-based relationships submodule **222**) and determining a distance, ratio, or other metric between the landmarks. The distance, ratio, or other metric may represent at least part of the relationship between the first and second landmarks.

In an embodiment, the first facial feature may include an eyebrow of the subject and the second facial feature may include an eye of the subject. Various other combinations of features described with reference to FIGS. **5**A-B can be used in various embodiments.

At operation **404**, processing logic determines, among multiple eye types, a first eye type corresponding to an eye of the subject. Eye types are further described with reference to FIGS. **9**-**10**.

At operation **405**, processing logic identifies, among multiple false eyelashes, a subset of the plurality of false eyelashes based on the relationship between the first landmark and the second landmark of the 3D model. In some embodiments, the plurality of false eyelashes may be false eyelashes of false eyelash database **236** (e.g., false eyelashes **310**A-N), the subset may be included in one of false eyelash notifications **252**, **320**, or **330**, and the relationship may be included in 2D relationship data **232** or 3D relationship data **234**. In some embodiments, the subset of false eyelashes includes artificial lash extensions designed for application at an underside of natural eyelashes. In some embodiments, the subset of false eyelashes may include false eyelash configurations each including multiple false eyelashes. For example, the subset may include lash configuration information for artificial lash extensions.

In some embodiments, identifying the subset further includes determining a range for a value of a characteristic associated with each of the multiple of false eyelashes, wherein the determined range corresponds to the determined relationship. The range may be a single value. The range may be a continuous range, a discrete range, an enumerate list, etc. In some embodiments, identifying the subset further includes identifying false eyelashes corresponding to respective values of the characteristic that are within the determined range. In some embodiments, the subset of false eyelashes can be identified from a table or matrix. For example, a Structured Query Language (SQL) query including the determined range(s) can be used to identify the subset from a database table.

In some embodiments, identifying the subset further includes identifying false eyelashes associated with characteristics that correspond to user preference data (e.g., false eyelashes associated with a user-selected style preference).

At operation **406**, processing logic provides, for presentation at a client device, an indication of the subset of false eyelashes. In some embodiments, the indication may be one of false eyelash notifications **252**, **320**, or **330**, and the client device may be client device **110**. The indication may be presented on a UI of client device **110** (e.g., of application **119**).

At operation **407**, processing logic receives an indication of a user selection of a first false eyelash from the subset of false eyelashes. In some embodiments, the indication may be false eyelash selection **264**.

At operation **408**, processing logic generates, for presentation at a client device, an updated 2D image of the eye area of the subject, the updated 2D image representing the first false eyelash applied to the eye area of the subject. In some embodiments, the updated 2D image may be included in false eyelash media content **282** and may be generated by augmented reality module **270**. In some embodiments, the updated 2D image represents one or more artificial lash extensions applied to the underside or topside of natural lashes of the subject.

FIG. **5**A illustrates a depiction of a human face **500**, in accordance with embodiments of the disclosure. Human face **500** is illustrated as a 2D representation of a 3D model for purposes of illustration, rather than limitation. Points on the human face **500** are described here as 3D points of a 3D model, for purposes of illustration rather than limitation. It should be noted that the description of FIG. **5**A can apply equally to a 2D image and/or 2D points, unless otherwise described.

In some embodiments, multiple reference points (e.g., 3D points **510**-**532**) can correspond to or represent facial features of the human face **500**. In some embodiments, a number of 3D points **510**-**532** that correspond to each 3D landmark can be the same. For example, the number of 3D points corresponding to the nose can be the same as the number of 3D points corresponding to the mouth. In some embodiments, the number of 3D points **510**-**532** that correspond to each 3D landmark can be different. In some embodiments, the number of 3D points **510**-**532** that correspond to each 3D landmark can be based on an importance of the 3D landmark. For example, a machine learning model can determine that the nose has a higher importance than the mouth, and more 3D points can be generated and/or used to correspond to the nose than to the mouth. In some embodiments, the number of 3D points that correspond to each 3D landmark can be determined by the training set generator **131** or model **160** of FIG. **1**, and/or received as input to the model **160** or training set generator **131**.

As illustrated in FIG. **5**A, 3D points **510**A-**524**A correspond to one half of the face. 3D points **510**B-**524**B (not illustrated) correspond to the other half of the face, but for clarity, are not labeled in FIG. **5**A. It can be appreciated that each of the illustrated 3D points **510**A-**524**A corresponds to a respective 3D point **510**B-**524**B opposite the centerline (e.g., symmetric about the centerline). 3D points **525**-**531** line on, or near the centerline **501**. As used herein, 3D points **510**-**532** can collectively refer to 3D points **510**A-**524**A, 3D points **510**B-**524**B (also, referred to herein as 3D points **510**A/B-**524**A/B), and 3D points **525**-**531**. As used herein, 3D points **510**-**532** can be referred to individually such as "3D point **510**A," or "3D point **510**B," or "3D point **510**A/B," or "3D point **510**," or "3D point **525**" respectively as applicable.

It can be appreciated that the 3D points **510**-**532** do not represent an exhaustive list of 3D reference points for a human face but are merely illustrative of the types of 3D reference points that can be used by a machine learning model in the process of identifying 3D landmarks that correspond to facial features based on human face data (e.g., 2D image data). In some embodiments, one or more 3D points **510**-**532** can correspond to one or more 3D landmarks of 3D landmark data. In some embodiments, corresponding 2D points can correspond to one or more facial features of 2D facial feature data.

3D Landmark Data

In some embodiments, the following illustratively named 3D points and groups of 3D points **510**-**532** (as described herein below) can represent 3D landmark data of the human face **500**, such as 3D landmark data **216** of FIG. **2**A. In some embodiments, corresponding 2D points (which may be located at similar x-, y-coordinate positions as respective 3D points **510**-**532**) can represent 2D facial feature data of the human face **500**. For example, 3D point **525** can be representative of a "center point of the face," and can correspond to a 3D landmark.

In another example, centerline **501** approximately intersects a majority of the 3D points **525**-**532** and can represent the "centerline of the face," and can represent a 3D landmark of 3D landmark data. In another example, the horizontal line **502** approximately intersects a majority of 3D points **511**A/B, **518**A/B, **517**A/B, and **525**, and can be a 3D landmark of 3D landmark data.

In some embodiments, 3D point **510** can be representative of an "outer brow corner."

In some embodiments, 3D point **511** can be representative of a "center of the pupil" or "eye center." As used herein, "pupil" can refer to the adjustable opening in the center of the eye that regulates the amount of light entering the eye. Generally, the pupil can be dark in color (e.g., black), and is surrounded by the iris. As used herein, "iris" can refer to a colored muscular structure that can contract or dilate to control the size of the pupil (e.g., to control the amount of light entering the eye). The iris is surrounded by the sclera. As used herein, "sclera" can refer to a light-colored (e.g., white, or nearly white) outer layer that protects maintains the structural integrity of the eyeball.

In some embodiments, 3D point **512** can be representative of a "brow apex."

In some embodiments, 3D point **513** can be representative of an "inner brow corner."

In some embodiments, 3D point **514** can be representative of an "inner eye corner."

In some embodiments, 3D point **515** can be representative of an "eye apex."

In some embodiments, 3D point **516** can be representative of an "eye bottom (nadir)."

In some embodiments, 3D point **517** can be representative of a "temporomandibular joint (TMJ)."

In some embodiments, 3D point **518** can be representative of an "outer eye corner."

In some embodiments, 3D point **519** can be representative of a "cheekbone," or "upper cheek."

In some embodiments, 3D point **520** can be representative of an "alar wing."

In some embodiments, 3D point **521** can be representative of a "mouth corner."

In some embodiments, 3D point **522** can be representative of a "lower cheek."

In some embodiments, 3D point **523** can be representative of a "chin." As illustrated, in some embodiment, 3D point **523** is located based on the position of 3D point **521** (e.g., the mouth corner) outline of the shape of the human face (e.g., a lower jawline).

In some embodiments, 3D point **524** can be representative of a "temple."

In some embodiments, 3D point **525** can be representative of a "center point," and/or the "center of the bridge of the nose."

In some embodiments, 3D point **526** can be representative of a "nose tip."

In some embodiments, 3D point **527** can be representative of a "nose bottom (nadir)."

In some embodiments, 3D point **528** can be representative of a "lips apex."

In some embodiments, 3D point **529** can be representative of a "lips center."

In some embodiments, 3D point **530** can be representative of a "lips bottom (nadir)."

In some embodiments, 3D point **531** can be representative of a "chin bottom (nadir)."

In some embodiments, 3D point **532** can be representative of a "forehead apex."

In some embodiments, 3D points **510**, **512**, and **513** can be representative of the "brow" or "eyebrow" facial feature.

In some embodiments, 3D points **511**, **514**, **515**, **516**, and **518** can be representative of the "eye" facial feature.

In some embodiments, 3D points **510-513** can be representative of an "eyelid area" facial feature.

In some embodiments, 3D points **510-518** can be representative of the "eye area" facial feature.

In some embodiments, 3D points **520**A/B, and **525-527** can be representative of the "nose" facial feature.

In some embodiments, 3D points **521**A/B and **528-530** can be representative of the "mouth" facial feature.

In some embodiments, 3D points **519** and **522** can be representative of the "cheek" facial feature.

In some embodiments, 3D points **517**A/B, **523**A/B and **531** can be representative of the "jawline," or "lower face shape" facial feature.

In some embodiments, 3D points **523**A/B and **530-531** can be representative of the "chin" facial feature.

3D Geometric Data

3D geometric data (e.g., 3D geometric data **246**A) can describe a scene or object, and can include one or more vertices (e.g., points), edges, and/or faces of a 3D model represented by 3D model data (e.g., 3D model data **233**A). In some embodiments, 3D geometric data can be represented by x-, y-, z-coordinate positions of one or more 3D points. For example, an x-, y-, z-coordinate position of the nose tip (e.g., 3D point **526**) can represent a portion of 3D geometric data.

In some embodiments, 3D geometric data can be represented as a relationship between two or more 3D points of a particular facial feature. For example, a distance between the 3D point **520**A and the 3D point **520**B can represent a portion of 3D geometric data. In another example, centerline **501** can represent a relationship (e.g., a distance) between 3D point **531** and 3D point **532** as a "face height." In another instance, horizontal line **502** can represent a relationship (e.g., a distance) between 3D points **517**A/B as a "face width." In some embodiments, 2D geometric data can similarly be represented by x-, y-coordinate positions of a 2D point, or a relationship between two or more 2D points. In some embodiments, a relationship between two or more points (e.g., two or more 2D points or two or more 3D points) can correspond to a facial feature.

In some embodiments, a relationship between 3D point **510**A and 3D point **510**B can represent an "outer brow width."

In some embodiments, a relationship between 3D point **511**A and 3D point **511**B can represent an "inner pupillary distance (IPD)."

In some embodiments a relationship between 3D point **513**A and 3D point **513**B can represent an "inner brow distance."

In some embodiments, a relationship between 3D point **518**A and 3D point **514**A can represent an "eye width."

In some embodiments, a relationship between 3D point **514**A and 3D point **514**B can represent an "inner eye corner distance."

In some embodiments, a relationship between 3D point **520**A and 3D point **520**B can represent a "nose width."

In some embodiments, a relationship between 3D point **525** and 3D point **527** can represent a "nose height."

In some embodiments, a relationship between 3D point **521**A and 3D point **521**B can represent a "mouth width."

In some embodiments, a relationship between 3D point **528** and 3D point **530** can represent a "mouth height."

3D Landmark Relationship Data

3D landmark relationship data (e.g., 3D landmark relationship data **247**A) can describe a relationship between first information corresponding to a first facial feature (e.g., 3D landmark data **245**A or 3D geometric data **246**A) and second information of a second facial feature (e.g., a relationship between two or more facial features). In some embodiments, 3D geometric data can describe relationships between 3D points corresponding to the same facial feature (e.g., lengths, distances, ratios, etc. derived between 3D landmark data and 3D geometric data), 3D landmark relationship data can describe relationships between 3D points corresponding to different facial features. For example, a ratio of the length of the centerline **501** to the length of the horizontal line **502** can represent 3D landmark relationship data. In another example, a difference between a first slope of the horizontal line **502** and a second slope of a line between the inner and outer eye corners (e.g., 3D points **514** and **518** respectively) can be expressed as an angle and represent 3D landmark relationship data. In another example, a difference in the x-, y-, z-coordinate position of the 3D points representing the nose and 3D points representing an eye can be expressed as a ratio or distance and represent 3D landmark relationship data. In another example, a relationship between a width of the nose (e.g., first facial feature), and a width of an eye (e.g., second facial feature) can be a portion of 3D landmark relationship data. A specific illustrative example of 3D landmark relationship data is described below with reference to FIG. **5**B. In some embodiments, 2D facial feature relationship data can similarly describe relationships between 2D points of two or more (different) facial features (e.g., based on 2D facial feature data **242**A, and 2D geometric data **243**A).

FIG. **5**B illustrates a depiction of an eye area **580** of a human face, in accordance with embodiments of the disclosure. In some embodiments, the human face can be a human face **500** as described with reference to FIG. **5**A. Eye area **580** includes 3D relationships **581-586** and 3D relationships **587-593** (also referred to collectively as "3D relationships **581-593**") between 3D points **510-519** as illustrated above in FIG. **5**A. In some embodiments, the illustrative depictions of 3D relationships **581-593** can represent relationships between 3D points (e.g., 3D geometric data **246**A). In some embodiments, the illustrative depictions of 3D relationships **581-593** can represent relationships between 3D landmarks (e.g., 3D landmark relationship data). In some embodiments, 3D relationships, such as 3D relationships **581-593**, can represent 3D landmark relationship data.

Eye area **580** is illustrated as a 2D representation of a 3D model for purposes of illustration, rather than limitation. Points on eye area **580** are described here as 3D points of a 3D model, for purposes of illustration rather than limitation. It should be noted that the description of FIG. **5**B can apply equally to a 2D image and/or 2D points unless otherwise described.

As illustrated in FIG. **5**B, 3D relationships **581-593** correspond to one half of the face. It can be appreciated that for clarity, each of the 3D relationships **581-593** have been illustrated only on one half of the face, but that each of the 3D relationships **581-593** can correspond to either side of the face (not illustrated). It can be appreciated that the 3D relationships **581-593** do not represent an exhaustive list of relationships between reference points for the eye area **580** a human face, but are merely illustrative of the types of relationships that can be used by a machine learning model in the process of identifying 3D landmark relationship data (e.g., 3D relationship data **234**) based on image input data (e.g., 2D image data **204** and 3D model data **214**). In some embodiments, relationships represented in 2D facial feature relationship data (e.g., 2D relationship data **232**) can similarly be identified by a machine learning model based on image input data (e.g., 2D image data **204** and 3D model data **214**).

In some embodiments, multiple relationships (e.g., represented by 3D geometric data) between reference points (e.g., 3D points **510-532**) can correspond to or represent facial features of the eye area **580**. In some embodiments, a number of relationships (e.g., represented by 3D geometric data) that correspond to each facial feature can be the same (e.g., each facial feature has an equal number of relationships), or can be based on an importance of the facial feature (e.g., more important facial features (for example, as determined by an algorithm or machine learning model) have a higher number of relationships than less important facial features). In some embodiments, multiple relationships represented by 2D geometric data can similarly correspond to or represent facial features of the eye area **580**.

In some embodiments, multiple relationships (e.g., represented by 3D landmark relationship data) between 3D landmarks represented in the eye area **580** can correspond to facial features of the eye area **580**. In some embodiments, a number of relationships (e.g., represented by 3D relationship data **234**) can be based on an importance of the facial feature, such as an importance determined by an algorithm or machine learning model (e.g., more important 3D landmarks can have a higher number of relationships to other 3D landmarks than less important 3D landmarks).

In some embodiments, 3D relationship **581**A can span between 3D point **510**A and 3D point **511**A (e.g., between the outer brow corner and the eye, such as the pupil or center of the pupil).

In some embodiments, 3D relationship **582**A can span between 3D point **512**A and 3D point **511**A (e.g., between the brow apex and the eye, such as the pupil or center of the pupil).

In some embodiments, 3D relationship **583**A can span between 3D point **513**A and 3D point **511**A (e.g., between the inner brow corner and the eye, such as the pupil or center of the pupil).

In some embodiments, 3D relationship **584**A can span between 3D point **515**A and 3D point **518**A (e.g., between the eye apex and the outer eye corner).

In some embodiments, 3D relationship **585**A can span between 3D point **514**A and 3D point **518**A (e.g., between the inner eye corner and the outer eye corner).

In some embodiments, 3D relationship **586**A can span between 3D point **514**A and 3D point **515**A (e.g., between the eye apex and the inner eye corner).

In some embodiments, 3D relationships **587-593** can span between 3D point **525** (e.g., the center point) and respective 3D points of the eye area **580**.

For example, 3D relationship **587**B can span between 3D point **525** and 3D point **513**A (e.g., the inner brow corner).

For example, 3D relationship **588**B can span between 3D point **525** and 3D point **512**A (e.g., brow apex).

For example, 3D relationship **589**B can span between 3D point **525** and 3D point **510**A (e.g., outer brow corner).

For example, 3D relationship **590**B can span between 3D point **525** and 3D point **515**A (e.g., eye apex).

For example, 3D relationship **591**B can span between 3D point **525** and 3D point **519**A (e.g., checkbone).

For example, 3D relationship **592**B can span between 3D point **525** and 3D point **514**A (e.g., inner eye corner).

For example, 3D relationship **593**B can span between 3D point **525** and 3D point **516**A (e.g., eye bottom (nadir)).

In some embodiments, a ratio between two or more 3D relationships **581-593** corresponding to different facial features can represent a relationship between two or more 3D landmarks (e.g., 3D relationship data **234**). Similarly, in some embodiments, a ratio between two or more 2D relationships corresponding to different facial features can represent a relationship between two or more 2D facial features (e.g., 2D relationship data **232**).

For example, for the facial features of the brow (e.g., represented by 3D points **510**, **512**, and **513**) and the eye (represented by 3D points **511**, **514**, **515**, **516**, and **518**), a ratio between the eye width (e.g., 3D relationship **585**A) and the brow height (e.g., 3D relationship **582**A) can be 3D landmark relationship data expressed as a ratio of eye-width to brow-height.

In some embodiments, an angle between two or more 3D relationships **581-593** corresponding to different facial features can represent a relationship between two or more 3D landmarks (e.g., 3D relationship data **234**). Similarly, in some embodiments, an angle between two or more 2D relationships corresponding to different facial features can represent a relationship between two or more 2D facial features (e.g., 2D relationship data **232**).

For example, the facial feature of the horizontal line **502** and the eye (represented by 3D points **511**, **514**, **515**, **516**, and **518**), an angle between the 3D relationship **585**A (e.g., the relationship corresponding to the eye width) and the horizontal line **502** can be 3D landmark relationship data expressed as an angle representing "eye slant."

FIG. **6** is an illustration of an exemplary artificial lash extension with a textured base, in accordance with some embodiments of the disclosure. FIG. **7** is an illustration of another exemplary artificial lash extension with a textured base, in accordance with some embodiments of the disclosure.

In some embodiments, one or more of artificial lash extension **600** or artificial lash extension **700** (both also referred to as "lash extension," "artificial eyelash extension," "lash segment" or "artificial lash segment" herein) are designed or configured for application at the underside of the natural eyelashes of the user, or alternatively, even the top side of the natural eyelashes of a user. In some embodiments, one or more of artificial lash extension **600** or artificial lash extension **700** can be part of a set of multiple artificial lash extensions. In some embodiments, one or more of artificial lash extension **600** or artificial lash extension **600** can be a segment of a "full" artificial lash extension such that when multiple artificial lash extensions are arranged adjacent to one another at the underside of natural eyelashes the arranged artificial lash extensions span the length of the natural eyelashes to form a full artificial lash extension. In some embodiments, the artificial lash extensions (e.g., segments) can be shorter than the horizontal length of the natural eyelashes (e.g., length of the lash line). In some embodiments, 3-5 artificial lash extensions can be arranged adjacent to one another at the underside of the natural eyelashes so that the set of arranged artificial lash extensions span the length of the natural eyelashes. In other embodiments, an artificial lash extension can be longer such that the artificial lash extension is a "full" artificial lash extension that substantially spans the horizontal length of the natural eyelashes. The artificial lash extension can be arranged to substantially align with the lash line of the user. In some embodiments, using artificial lash extensions that are independent segments can allow an individual artificial lash extension to move independently when bonded to the underside of a natural lash, which mimics the movement of the natural lash and can improve the feel, comfort, and longevity of the artificial lash extensions.

Artificial lash extension **600** and artificial lash extension **700** respectively depict artificial hairs **602**A-**602**N (collectively referred to as "artificial hairs **602**" herein) and **702**A-**702**N (collectively referred to as "artificial hairs **703**" herein). In some embodiments, the artificial hairs of an artificial lash extension, such as artificial lash extension **600** or artificial lash extension **700**, can be formed from one or more synthetic materials, including but not limited to polybutylene terephthalate (PBT), acrylic resin, polyester (e.g., polyethylene terephthalate (PET)), other polymers, other synthetic material, or a combination thereof. In alternative embodiments, a natural material such as natural hair (e.g., human hair or mink hair) can be used. In some embodiments, the artificial hairs of a particular artificial lash extension can have one or more lengths and/or one or more diameters. In some embodiments, the diameter of an artificial hair can be between approximately 0.0075 millimeters (mm) (e.g., 0.0075 mm+/−0.0025 mm) to 0.3 mm (e.g., 0.3 mm+/−0.05 mm). In some embodiments, the ends of one or more of the artificial hairs can be tapered. In some embodiments, the one or more of artificial hairs can be curled or shaped in a particular direction. For example, the ends **608** of artificial hairs **602** or the ends **708** of artificial hairs **702** can be tapered or curled or both. In another example, the ends **608** of artificial hairs **602** can be curled upwards in the direction of the top side of the artificial lash extension **600**. In some embodiments, the artificial hairs can range from 3 mm to 30 mm in length, or in some instances even longer.

In some embodiments, artificial lash extension **600** of FIG. **6** and artificial lash extension **700** FIG. **7** can include multiple sides, such a front side, a rear side, a top side, a bottom side, a first end, and a second end opposite the first end. The sides are described relative to an orientation of an artificial lash extension when attached to a user's natural eyelashes, for the sake of illustration, rather than limitation. Referring to artificial lash extension **600** of FIG. **6**, the front side **612** can refer to a side that is a forward part of the artificial lash extension. For example, the front side **612** of artificial lash extension **600** faces opposite the user when attached to a user's natural eyelashes. The back side **614** can refer to a side that is opposite the front side **612** and faces the user's face when attached to a user's natural eyelashes. The top side **616** can refer to an uppermost part and faces towards the top of the user's head when attached to a user's natural eyelashes. The bottom side **618** is opposite the top side **616** and faces towards the user's feet when attached to a user's natural eyelashes. The first end **620** and the second end **622** can refer to lateral parts or lateral sides of an artificial lash extension. For example, the first end **620** can be a left side and the second end **622** can be a right side (or vice versa) when the artificial lash extension is attached to the user's natural eyelashes. Although multiple sides are described with respect to artificial lash extension **600**, artificial false eyelashes and other artificial lash extensions, such as artificial lash extension **700** can be described having similar sides. Additionally, the sides as described with respect to an artificial lash extension **600** can also be used to describe sides of a base of an artificial lash extension, as further described below.

In some embodiments, an artificial lash extension can include a base. For example, artificial lash extension **600** includes base **606**. In some embodiments, artificial lash extension **700** may or may not (as illustrated) include a base similar to base **606** of artificial lash extension **600**. The base can include a top side (e.g., facing out of the page and towards the reader), a bottom side, a back side, a front side, and two ends (e.g., two lateral sides). In some embodiments, one or more of the multiple artificial hairs of artificial lash extension protrude out the front side of the base. When arranged at the underside of a natural lash, the backside of the artificial lash extension can point towards the user's eye. The thickness (e.g., between the top side and bottom side of the base can be between approximately 0.05 millimeters (mm) and approximately 0.15 mm (e.g., 0.05 mm+/−0.01 mm). In some embodiments, the thickness of the base can be less than 0.05 mm. In some embodiments, the low profile of the base is designed to allow the artificial lash extension to be light weight to better adhere to the underside of the natural lash and prevent obstruction of a user's view. The low profile of the base can at least in part be attributed to an attachment operation that forms the base and/or attaches clusters of artificial hairs to the base. For example, the attachment operation can include an application of heat that, at least in part, creates a base with a low profile.

In some embodiments, one or more of the top side or bottom side (e.g., surface) of the base is substantially flat (e.g., having a flatness control tolerance value of +/−0.03 mm or +/−0.015 mm). In some embodiments, the flatness of the base of the artificial lash extension **600** is designed to allow improved contact and adhesion to a surface, such as the underside of a natural eyelash or the opposing surface of another artificial lash extension. The flatness of the base can at least in part be attributed to the attachment operation.

In some embodiments, one or more of artificial lash extension **600** of FIG. **6** and artificial lash extension **700** of FIG. **7** include artificial hairs **602** and **702** that are respectively configured into clusters of artificial hairs **604**A-**604**G (collectively referred to as "clusters **604**" or "clusters of artificial hairs **604**" herein) and clusters of artificial hairs **704**A-**704**G (collectively referred to as "clusters **704**" or "clusters of artificial hairs **704**" herein). In some embodiments, a cluster of artificial hairs can refer to two or more artificial hairs that are grouped together. In some embodiments, one or more artificial hairs of a cluster of artificial hairs contact one another at or near the base. In some embodiments, two or more artificial hairs of a cluster can contact one another before and/or after an attachment operation, such as an application of heat. In some embodiments, 2-30 artificial hairs can be included in a cluster.

In some embodiments, the clusters of artificial hairs can be connected to or at the base with an application of heat in a similar manner as described herein (e.g., attachment operation). In some embodiments, the application of heat can at least partially melt at least some of the artificial hairs of one or more clusters of the artificial lash extension. In some embodiments, the application of heat can at least partially melt at least some of the artificial hairs of at least one cluster so that at least some of the artificial hairs of the cluster connect to one another. In some embodiments, the application of heat can at least partially melt at least some of the artificial hairs of at least one cluster so that at least some of the artificial hairs of the cluster connect to the base of the artificial lash extension (and/or form, at least in part, the base of the artificial lash extension). In some embodiments, at least some of the artificial hairs of at least one clusters are connected to one another at a respective part of the base by at least the application of heat.

In some embodiments, the clusters are connected to one another at the base by the application of heat. In some embodiments, one or more of the clusters of the artificial lash extension are directly connected to at least one adjacent cluster at the base. In some embodiments, one or more of the clusters of the artificial lash extension are indirectly connected to at least one adjacent cluster of the artificial lash extension at the base.

In some embodiments, at least two artificial hairs of an artificial lash extension crisscross each other. For example, two artificial hairs of a particular cluster can crisscross one another. In some embodiments, one or more individual clusters of artificial hairs can be formed using an application of heat as described above. Thus, the clusters can have a base (e.g., cluster base). The clusters can be arranged, and heat can be applied, as described above, to the cluster bases to form at least in part the base (e.g., base **606**) of the artificial lash extension. In some embodiments, artificial lash extensions **600** or **700** may be 4-10 mm wide. In some embodiments, artificial lash extension **600** or **700** may be 5-6 mm wide. In some embodiments, the width of an artificial lash extension is much wider than a single cluster that is typically 1-2 mm wide.

Artificial lash extension **700** of FIG. **7** further illustrates adjacent artificial hairs (or adjacent clusters **704**) that are coupled or secured to one another at connecting portions **710**A-**710**H (collectively referred to as "connecting portions **710**" herein) of the crisscrossing artificial hairs **702**. For example, at least one hair of a particular cluster can be secured (e.g., directly or indirectly) to one or more hairs of an adjacent cluster at a connecting portion. In some embodiments, connecting portions **710** can connect artificial hairs (e.g., clusters) of an artificial lash extension together at areas between the two ends of the artificial hairs such that the artificial hairs of the artificial lash extension are connected directly or indirectly to one another to form an artificial lash extension and both ends of the artificial hairs not connected together (e.g., open ended).

In some embodiments, the connecting portions **710** (also referred to "base **710**" herein) can be considered a base, as described herein. In some embodiments, the connecting portions **710** can be formed by an attachment operation, as described herein. In some embodiments, the connecting portions **710** can be formed by an attachment operation that includes an application of heat in a similar manner as described herein. In some embodiments, the connecting portions **710** can be formed by an attachment operation that includes an application of pressure in a similar manner as described herein. In some embodiments, the connecting portions **710** can be formed using one or more of an application of heat, an application of adhesive, an application of pressure, or a chemical process as described herein. For example, the crisscrossing artificial hairs **702** are connected or secured together approximately 1 mm to approximately 5 mm (+/−0.5 mm) above the ends **706** of the artificial hairs **702** (e.g., the ends **706** that are opposite the ends **708**) using an attachment operation.

In some embodiments, the clusters can be secured to one another above ends **706** using an attachment operation that includes an artificial material to form connecting portions **710**. In some embodiments, additional artificial material such as one or more artificial hairs or other material(s) can be placed or connected horizontally with respect to the lengthwise direction of the artificial hairs (e.g., across the area designated by the connecting portions **710**). The artificial hairs or clusters of artificial hairs can be connected to the additional artificial material using an attachment operation that includes one or more of an application of heat, an application of adhesive, an application of pressure, a chemical process, or a thread as described herein. In some embodiments, the application of the additional artificial material that is used to connect the artificial hairs of artificial lash extension **700** can be similar to the application of additional artificial material used to form a base as described herein.

In some embodiments, the base (similar to base **606** of artificial lash extension **600**) can be formed and subsequently removed after the formation of the connecting portions **710**, such that the artificial lash extension **700** does not include the base similar to base **606**. In some embodiments, the secured connecting portions **710** can hold artificial hairs **702** of the artificial lash extension **700** together in the absence of a base similar to base **606**. In some embodiments, the connecting portions **710** of the crisscrossing artificial hairs **702** can be formed without forming a base that similar to base **606** of artificial lash extension **600**.

It should be appreciated that artificial lash extension **600** and **700** are provided for purposes of illustration, rather than limitation.

In some embodiments, each artificial lash extension in a set of lash extensions can include multiple clusters of artificial hairs and a base (e.g., such as base **606** or a base including connecting portions **710**). In some embodiments, at least the base of the artificial lash extension can include a surface that is textured, such as texture **610** of base **606** or texture **712**A through **712**H (generally referred to as "texture **712**" herein) of connecting portions **710** (also referred to as a base). In some embodiments, the texture, such a texture

610 or texture **712** of a base can promote adhesion to a surface, such as an underside of natural eyelashes, using an adhesive.

In other embodiments, different parts of the artificial lash extension can be textured (including or not including the textured base) to help promote adhesion to a surface using an adhesive.

In some embodiments, the texture can have a pattern. A patterned texture can have at least some repeating features and/or a repeating arrangement of features. In some embodiments, the pattern texture is symmetrical. In some embodiments, the texture can be unpatterned. A patterned texture can also result from, for example, pressing, molding, or stamping the artificial lash extension such that the pressing, molding, or stamping results in a roughened or indented surface on the artificial lash extension. An unpatterned texture can have non-repeating features and/or a non-repeating arrangement of features.

In some embodiments, the surface of the top side of the base is textured, and the surface of the bottom side of the base (opposite the top side of the base) is untextured (e.g., substantially smooth, or at least not intentionally textured). In some embodiments, the surface of the top side of the base is textured, and the surface of the bottom side of the base is different from the textured surface of the top side of the base.

In some embodiments, the base of an artificial lash extension can be a single unit (e.g., monolithic) formed of a first material, such as PBT or polyester. In some embodiments, the texture, such as texture **610** and **712**, and can be formed in the first material and be part of the single unit. Artificial lash extension **600** and artificial lash extension **700** illustrate example artificial lash extensions having a base and a texture thereon formed as a single unit. In some embodiments, the texture of the base is intentionally or deliberately formed to promote adhesion to a surface, such as the underside of natural eyelashes. In some embodiments, the texture of the base is intentionally or deliberately formed using a texturing operation.

FIG. **8** depicts an arrangement of artificial lash extensions in accordance with lash configuration information, in accordance with some embodiments. Set of artificial lash extensions **800** illustrates artificial lash extensions **811** through **815**. The description of lash configuration information with respect to artificial lash extensions is provided for purposes of illustration, rather than limitation. It can be noted that in other embodiments, lash configuration information can be implemented for false eyelashes, generally. It can be further noted that in other embodiments, a set of artificial lash extensions can have any number of artificial lash extensions. For purposes of illustration, rather than limitation a set of artificial lash extensions with respect to FIG. **8** is described as for a single eye. It can also be noted that in other embodiments that a set of artificial lash extensions can be for a pair of eyes, multiple eyes, or object or configurations.

Lash configuration information (also referred to as "lash map" herein) can refer to information related to the selection of artificial lash extensions and/or the application of artificial lash extensions at the eye area of a user. In some embodiments, lash configuration information can identify the particular artificial lash extensions of a set of lash extensions (e.g., length, style, and/or color), a location at the underside of the natural lashes at which each particular artificial lash extension of the set of artificial lash extensions is to be applied, and/or the order of each artificial lash extension in the set of artificial lash extensions. In some embodiments and as described further below, lash configuration information can include one or more of style information, length information, color information, placement information, or order information for an eye or pair of eyes of a user. An example of lash configuration information is illustrated in element **835**.

In some embodiments, lash configuration information can be specific to a particular user. In some embodiments, lash configuration information can pertain to single eye where each eye of a pair of eyes can have different lash configuration information. In some embodiments, lash configuration information can pertain to a pair of eyes where each eye has the same or similar lash configuration information. In some embodiments, a set of artificial lash extension can include multiple artificial lash extensions for a single eye or a pair of eyes.

In some embodiments, lash configuration information includes style information. In some embodiments, style information can identify a style of one or more artificial lash extensions in a set of artificial lash extension. The style of an artificial lash extension can refer to a particular design of an artificial lash extension and/or a desired appearance of an arranged set of artificial lash extensions. In some embodiments, style or design of an artificial lash extension can be or can include a particular arrangement or pattern of artificial hairs of an artificial lash extension.

For example, artificial lash extensions **811** through **815** show artificial lash extensions of the set of artificial lash extensions **800** in a same style, style X (e.g., style information is style X). The artificial lash extensions of style X can have the same or similar arrangement (e.g., pattern) of artificial hairs. In other examples, one or more artificial lash extensions of a set of artificial lash extensions can be of different styles from other artificial lash extensions of the set of artificial lash extensions. For instance, artificial lash extension **813** can be of style P that is pointed at the ends (not shown) and the remining artificial lash extensions **811**, **812**, **814** and **815** can be of style X.

In some embodiments, the style of the artificial lash extensions in a set of artificial lash extensions can be the same or similar. In some embodiments, the style among at least some of the artificial lash extensions in a set of artificial lash extensions can be of one or more different styles. Styles can include, for example, natural style (e.g., moderate curl and volume), volume style (e.g., extra volume and pronounced curl), mega-volume style (e.g., deep curl and densely packed volume), classic style (e.g., moderate curl and balanced volume), wispy style (e.g., feathered, fine extensions that create a textured and soft appearance), spiky style (e.g., separated, uneven extensions with a jagged, textured look), crimped style (e.g., extensions that are intentionally crimped or zigzagged), etc.

In some embodiments, lash configuration information includes length information. Length information can refer to the length of an artificial lash extension. In some instances, length can be measured from the base to tip of the artificial hairs of the artificial lash extension (e.g., the tip of the longest artificial hair of the artificial lash extension). In some embodiments, the lengths of the artificial lash extensions in a set of artificial lash extensions can be the same length. In some embodiments, the lengths of the set of artificial lash extensions in a set of artificial lash extensions can be varying lengths. In some embodiments, the lengths of an artificial lash extension can range from 6 millimeters (mm) to 25 mm or 8 mm to 20 mm.

For example, artificial lash extension **811** can be 12 mm in length, artificial lash extension **812** can be 11 mm in length, artificial lash extension **813** can be 10 mm in length, artificial lash extension **814** can be 9 mm in length, and artificial lash extension **815** can be 8 mm in length. The length information can be 8 mm, 9 mm, 10 mm, 11 mm, 12 mm for the set of artificial lash extensions **800**, for instance. In another example, the artificial lash extensions in a set of artificial lash extensions can be the same length and the corresponding length information can be 9 mm, 9 mm, 9 mm, 9 mm, 9 mm, for instance.

In some embodiments, varying lengths of the artificial lash extension within a lash configuration can be strategically used to create different desired appearances (e.g., looks). Varying lengths can be used to achieve, for example, a natural, textured appearance with mixed lengths or to add dimension by incorporating longer and shorter lashes within the same set of artificial lash extensions. In further examples, varying lengths can be used to achieve appearances such as a cat-eye appearance (e.g., longer extensions towards the outer corners of the eyes, creating an uplifted and elongated effect reminiscent of the eye shape of a cat), a doll-eye appearance (e.g., longer lashes at the center of the eye, producing a wide-eyed look), textured appearance (e.g., a mix of different lash lengths and types for a multidimensional look), cleopatra appearance (e.g., extended, winged extensions at the outer corners of the eye), etc.

In some embodiments, lash configuration information includes color information. Color information can refer to the color(s) of an artificial lash extension. In some embodiments, artificial lash extensions in a set of artificial lash extensions **800** can be the same color. In some embodiments, artificial lash extensions in a set of artificial lash extensions **800** can be different colors. Colors can include, for example, black, blonde, auburn, blue, green, purple, pink, and so forth. In some embodiments, an artificial lash extension can include multiple colors. For example, multi-colored lash extensions can include ombre (e.g., gradual transition of color from base to tip of the artificial hairs of dark to light or one color to another), rainbow (e.g., designed with multiple colors in a spectrum), sunset (e.g., warm and fiery hues of a sunset, blending colors like red, orange, and pink), etc. In some embodiments, a user can match the color of the artificial lash extensions of set of artificial lash extensions **800** with the color of the user's eyebrows, head hair or other feature.

In some embodiments, lash configuration information includes order information. Order information can refer to information identifying for an artificial lash extension of a set of artificial lash extensions a position in an order (e.g., sequence) of an arrangement of the set of artificial lash extensions. The order information can identify relative position of each artificial lash extension of the set of artificial lash extensions **800** with respect to one another. For example, artificial lash extensions **815**, **814**, **813**, **812**, and **811** are to be ordered as A, B, C, D, E respectively. The order information for artificial lash extension **815** can reflect position A in the order of the arrangement. The order information for artificial lash extension **814** can reflect position B, and so forth.

In some embodiments, lash configuration information includes location information. Location information can include information identifying a location of the eye area where an artificial lash extension of a set of artificial lash extensions is to be applied. For example, artificial lash extensions **815**, **814**, **813**, **812**, and **811** are to be located at points **825**, **824**, **823**, **822**, and **821** respectively. In some embodiments, the location information can include information that identifies a location on the natural lashes (e.g., a location at the underside of the natural lashes) at which an artificial lash extension of the set of artificial lash extension is to be applied. In some embodiments, location information can help guide a user on applying the set of artificial lash extension at the natural lashes. In some embodiments, the location information can include a visible guide (e.g., picture of identifying location(s) at which to apply one or more artificial lash extensions). In some embodiments, the location information can include descriptive information, such as textual information, describing a location at which to apply an artificial lash extension. For instance, location information for artificial lash extension **815** can include information that artificial lash extension **815** is to be applied at the inner corner of the right eye. Location information for artificial lash extension **814** can include information indicating that artificial lash extension **814** is to be applied directly adjacent to artificial lash extension **815**, and so forth.

FIG. **9** is an example training set generator to generate training data for a machine learning model using information pertaining to one or more beauty targets and one or more non-beauty target, in accordance with embodiments of the disclosure. System **900** shows a training set generator **131**, training inputs **930**, and target outputs **940**. System **900** can include similar components as system **100**, as described in FIG. **1**. Components described with reference to system **100** of FIG. **1** can be used to describe system **900** of FIG. **9**.

In some embodiments, training set generator **131** generates training data that includes one or more training inputs **930**, and one or more target outputs **940**. The training data can include mapping data that maps the training inputs **930** to the target outputs **940**. Training inputs **930** can also be referred to as "features" or "attributes," herein. In some embodiments, training set generator **131** can provide the training data in a training set and provide the training set to the training engine **141** where the training set is used to train the model **160**.

As noted above, the human face is one or the most variable and complex of human features. Similarly, the physical appearance of facial features can vary significantly among individuals. Beauty, and in particular beauty of a human face, is multifaceted and can be found in various forms. Rather than a single beauty architype, beauty can be found in range of skin tones, body shapes, facial features shapes, facial features sizes, hair textures, and features generally. Beauty can include and vary between and among different ethnicities, races, genders, ages, abilities, and backgrounds. Similarly, beauty targets can also vary widely.

A beauty target (also referred to as "facial beauty target" or "facial target" herein) can refer to one or more qualities or attributes (e.g., physical characteristics, such as facial features), often of a human face, that are shared between a group. In some cases, the one or more qualities or attributes are preferred (e.g., desirable aesthetic) by an individual of group of people. In some embodiments, a beauty target can be defined by multiple images (e.g., 2D images) representing facial features of one or more individuals that share qualities and/or attributes. Similar to beauty, beauty targets can vary widely between people, cultures, and historical periods. Rather than a single beauty target, multiple beauty targets can co-exist and can include a range of skin tones, body shapes, facial features shapes, facial features sizes, hair textures, and features generally.

In some embodiments, a beauty target need not necessarily correspond to beauty, but rather be a target that is preferred by an individual or group of individuals. For instance, a group of makeup artist may desire a "beauty target" that looks like a face of troll, or some other whimsical or comical target.

A non-beauty target (also referred to as a "facial non-beauty target" herein) can refer to one or more qualities or attributes (e.g., physical characteristics, such as facial features), often of a human face, that are different from a beauty target. In some cases, the one or more qualities or attributes are not preferred (e.g., undesirable aesthetic) by an individual of group of people. The non-beauty target can include one or more qualities or attributes that deviate from a beauty target.

As illustrated in FIG. **9**, multiple beauty targets are represented by first beauty target input data **930**A through an m-th beauty target input data **930**M and first beauty target output data **940**A through m-th beauty target output data (corresponding to a first beauty target input data **930**A and an m-th beauty target input data **930**M, respectively). In some embodiments, a beauty target can be different from other beauty targets. For example, one or more facial features or relationships between facial features can be different among beauty targets. In some embodiments, a beauty target may share some qualities and/or attributes with other beauty targets, but not all qualities or attributes. For example, a first beauty target and an m-th beauty target can share the same facial feature information representing a particular facial feature, but not other facial feature information representing other facial features. For instance, a first beauty target and an m-th beauty target may both share the same representation of a nose, but not share the same representation of other facial features. Facial feature information can include, but is not limited to, one or more of 2D information (e.g., one or more of 2D image data, 2D facial feature data, 2D geometric data, 2D facial feature relationship data, or 2D variation information) and 3D information (e.g., one or more of 3D model data, 3D landmark data, 3D geometric data, 3D landmark relationship data, or 3D variation information). In some embodiments, information pertaining to facial features can include some or all facial feature information.

Non-beauty target input data **930**N and non-beauty target output data **940**N can correspond to a non-beauty target. For example, a particular facial feature of a first beauty target can have substantially different facial features information (e.g., 2D lengths, widths, or ratios) facial feature information of the non-beauty target. For example, and in some embodiments, a nose length-to-width ratio corresponding to a first beauty target can significantly deviate from a nose length-to-with ratio corresponding to a non-beauty target.

Training Inputs

In some embodiments, training inputs **930** can include one or more of a first beauty target input data **930**A through m-th beauty target input data **930**M, a non-beauty target input data **930**N (which can include one or more non-beauty targets having non-beauty target input data, also referred to collectively as "beauty target input data **930**A-N" herein), and a beauty target indication **930**X. It can be appreciated that for the purposes of brevity in FIG. **9**, only elements of the first beauty target input data **930**A are illustrated and described. The illustration and corresponding description of elements of the first beauty target input data **930**A, including first image input data **931**A, 2D image data **932**A, 3D model data **933**A, and correspondence data **934**A can similarly apply to m-th beauty target input data **930**M and non-beauty target input data **930**N (e.g., as first beauty image input **931**M/N, 2D image data **932**M/N (not illustrated), etc.), unless otherwise described.

In some embodiments, each beauty target input can correspond to a respective beauty target output data. For example, the first beauty target input data **930**A can correspond to the first beauty target output data **940**A. Similarly, and in some embodiments, the m-th beauty target input data **930**M can correspond to the m-th beauty target output data **940**M, and the non-beauty target input data **930**N can correspond to the non-beauty target output data **940**N. In some embodiments, each beauty target input data **930**A-N can include one or more image inputs (e.g., image input data) that represent a human face. For example, the first beauty target input data **930**A can include first image input data **931**A through Nth image input data (illustrated by the additional box behind the first image input data **931**A element in FIG. **9**).

In some embodiments and as noted above, each image input of each beauty target input data **930**A-N can correspond to a respective image output information of a respective beauty target output data **940**A-N. For example, the first image input data **931**A of the first beauty target input data **930**A can correspond to the first image output data **941**A of the first beauty target output data **940**A. In another example, an Nth image input of the first beauty target input data **930**A can correspond to an Nth image output information of the first beauty target output data **940**A.

In some embodiments, each image input data can include one or more of 2D image data, 3D model data, and/or correspondence data. For example, first image input data **931**A includes 2D image data **932**A representing a 2D image, 3D model data **933**A (e.g., based on the 2D image), and correspondence data **934**A, and an Nth image input data includes Nth 2D image data, Nth 3D model data, and Nth correspondence data. In some embodiments, each image input data can correspond to or be obtained from an image. For example, first image input data **931**A can be obtained from a first image (e.g., a 2D image), and Nth image data can be obtained from an Nth image.

In some embodiments, each respective image input (e.g., first image input data **931**A) can correspond to a distinct representation of a human face. For example, each image input data can correspond to an image of a human face (e.g., 2D image representing a human face). In some embodiments, each respective image input of a particular beauty target can correspond to the same human face or different human faces that share similar facial features. In some embodiments, each image input data can correspond to a respective image output data (e.g., first image input data **931**A corresponds to first image output data **941**A), and both can correspond to the same 2D image representing a human face. In some embodiments, each of different 2D images (e.g., Nth image) can correspond to respective image input data (e.g., Nth image input data) and image output data (e.g., Nth image output data).

In some embodiments, the 2D image data **932**A can represent an image of a scene. In some embodiments, the scene can include one or more objects, such as an image of a person. In some embodiments, the 2D image data **932**A can represent an image of a subject's face or a part of the subject's face (e.g., an image of a subject's eye area). In some embodiments, the 2D image data **932**A can represent a frontal face image. A frontal face image can refer to an image taken from a front-facing perspective. For instance, in a frontal face image the subject can look directly at the camera.

In some embodiments, the 2D image data **932**A can represent a still image. In some embodiments, the 2D image data **932**A can represent one or more video images of a video, such as video images of a video stream. In some embodiments, the 2D image data **932**A can include 2D coordinate information of points (e.g., pixels) of the 2D image (e.g., x- and y-coordinates). In some embodiments, the 2D image can lack depth information (e.g., depth information measured by a depth camera). In some embodiments, the 2D image data **932**A can include digital data (e.g., pixels) representing a digital image. In some embodiments, a 2D image may be represented in various formats such as joint photographic experts group (JPEG), portable network graphics (PNG), tag image file format (TIFF), etc. In some embodiments, 2D image data **932**A may include color information by for example, using values of a color model such as a red, green, blue (RGB) color model or other color model.

In some embodiments, 2D image data **932**A may identify one or more facial features of a target face. A target face can refer to a face that corresponds to a particular beauty target (e.g., first beauty target represented by first beauty target output data **940**A). As noted above, a facial feature can refer to a physical characteristic or element that is part of a human face. Facial features can include, but are not limited to the lips, nose, tip of the noise, bridge of the nose, eyes, inner eye, pupil, eyelids, eyebrows, inner eyebrow, outer eyebrow, center eyebrow, checks (e.g., check bones, etc.), jaw (e.g., jawline, etc.), and/or other facial features.

In some embodiments, the 2D image data **932**A can have fixed dimensional values (e.g., fixed width, height, and color depth, such as 24-bit). In some embodiments, the 2D image data **932**A can have variable dimensional values. In some embodiments, the 2D image data **932**A can include depth information. In some embodiments, the 2D image data **932**A can include metadata such as a timestamp, location information indicating where an image was taken, image sensor specifications, facial feature coordinates and identifiers, etc.

In some embodiments, 3D model data **933**A can represent a three-dimensional digital representation of a scene or object (e.g., a 3D model). In some embodiments, the 3D model data is derived or generating using the respective 2D image (e.g., the 2D image represented by 2D image data). In some embodiments, the 3D model data **933**A of a 3D model can include width information, height information, and depth information of the scene and/or object. The 3D model data **933**A can include geometric data that describes the corresponding scene or object. The geometric data can include one or more of vertices (e.g., points), edges, and/or faces. In some embodiments, vertices (e.g., nodes or points) can include points of a 3D model. A vertex can have 3D coordinates (e.g., x-, y-, and z-coordinates). The vertex can identify a location where one or more edges intersect. In some embodiments, an edge can include a line, such as a straight line and connect at least two vertices. In some embodiments, faces can include surfaces, such as planar surfaces, connecting edges (e.g., closed-loop edges). In some embodiments, one or more of vertices, edges and faces can define the geometry of a 3D model.

In some embodiments, the 3D model data **933**A of the 3D model can include texture information that describes an object's surface texture. In some embodiments, 3D model data **933**A does not include texture information. In some embodiments, 3D model data **933**A includes material information that can influence the appearance of a 3D model at rendering (e.g., how light reflects from the material). In some embodiments, 3D model data **933**A does not include material information. In some embodiments, the 3D model data **933**A includes lighting information that describes the interaction of light (and absence of light) with the scene or object. In some embodiments, 3D model data **933**A does not include lighting information. In some embodiments, 3D model data **933**A includes color information that indicates the colors of surface (e.g., faces) of a 3D model.

In some embodiments, correspondence data **934**A can include data that maps 3D points (e.g., vertices) of the 3D model data **933**A that represent a 3D model to 2D points (e.g., pixels) of the 2D image data **932**A that represent a 2D image. In some embodiments, correspondence data can indicate a relationship between (x-, y-) coordinates of a 2D point in 2D image data **932**A that represent a 2D image, and (x-, y-, z-) coordinates of a 3D point in 3D model data **933**A that represent a 3D model. In some embodiments, correspondence data **934**A can include information for each 3D point in the 3D model data **933**A that represent a 3D model (e.g., 1:1 mapping). In some embodiments, correspondence data **934**A can map a cluster or group of 2D points in the 2D image data **932**A that represent a 2D image to a single 3D point in the 3D model data **933**A that represent a 3D model (e.g., many-to-one (X:1) mapping), and vice versa. In some embodiments, correspondence data **934**A can be generated by performing one or more pre-processing operations on 2D image data **932**A to generate the 3D model data **933**A. In some embodiments, an algorithm or model, such as a principal component analysis (PCA) model can be used to transform the 2D image data **932**A into a new set of dimensions (e.g., 3D model data **933**A). Additional details regarding using a PCA model to generate a 3D model from 2D image data is described below with reference to FIGS. **11**-**14**B.

In some embodiments, beauty target indication **930**X can include an indication of a particular beauty target among the multiple beauty targets. For example, the beauty target indication **930**X can identify the first beauty target (e.g., first beauty target input data **930**A and a corresponding target output data, such as first beauty target output data **940**A) among the Nth beauty targets. In some embodiments, a machine learning model can be trained on multiple beauty target inputs (e.g., first beauty target input data **930**A through m-th beauty target input data **930**M, etc.) and outputs. At inference, a particular beauty target among the multiple beauty targets can be selected such that input data representing the subject's face can be compared to a particular beauty target (e.g., rather than to multiple beauty targets). In some embodiments, the beauty target indication **930**X can be implemented to provide a selection of a beauty target for comparison.

For example, the beauty target indication **930**X can identify a selected beauty target among multiple beauty targets. The beauty target indication **930**X can be provided to the training input to allow a machine learning model to put greater emphasis (e.g., weights) on the beauty target identified by the beauty target indication **930**X. In some embodiments and for example, at inference the trained machine learning model can receive a selection of a beauty target (e.g., user selection) and machine learning model can evaluate the subject's face against the selected beauty target (rather than multiple beauty targets). In some embodiments, the beauty target indication **930**X can be used by the training set generator **131** to determine which beauty target input **930**A-M to use to generate variation information **940**X.

As illustrated and in some embodiments, a single machine learning model can be trained with multiple beauty targets. In some embodiments, multiple machine learning models can be trained where each machine learning model is trained using a different beauty target. In such embodiments, a user or system can select a particular machine learning model that pertains to a particular beauty target.

Target Outputs

In some embodiments, target outputs **940** can include one or more of a first beauty target output data **940**A through m-th beauty target output data **940**M, a non-beauty target output data **940**N (which can include one or more beauty targets having respective beauty target output data, also referred to collectively as "beauty target output data **940**A-N" herein), and a variation information **940**X. It can be appreciated that for the purposes of brevity in FIG. **9**, only elements of the first beauty target output data **940**A are illustrated and described. The illustration and corresponding description of elements of first beauty target output data **940**A, including first image output data **941**A, 2D facial feature data **942**A, 2D geometric data **943**A, 2D facial feature relationship data **944**A, 3D landmark data **945**A, 3D geometric data **946**A, and 3D landmark relationship data **947**A can similarly apply to the m-th beauty target output data **940**M, and the non-beauty target output data **940**N, unless otherwise described.

As described above and in some embodiments, each beauty target can correspond to respective beauty target input data and beauty target output data. That is, the training set generator **131** can generate a respective beauty target output data **940**A-N for each respective beauty target input data **930**A-N. For example, the training set generator **131** can generate the first beauty target output data **940**A for the first beauty target input data **930**A, respectively. In some embodiments, each beauty target **940**A-N can include one or more sets of image output data that represent a human face. For example, the first beauty target output data **940**A can include first image output data through Nth image output data (illustrated by the additional box behind the first image output data **941**A element in FIG. **9**). In some embodiments, each respective image output data can correspond to a particular 2D image.

Similarly, as described above and in some embodiments, each image output data in each beauty target output data **940**A-N can correspond to a respective image input data of a respective beauty target input data **930**A-N. For example, the first image output data **941**A of the first beauty target output data **940**A can correspond to the first image input data **931**A of the first beauty target input data **930**A, and an Nth image output data of the first beauty target output data **940**A can correspond to an Nth image input data of the first beauty target input data **930**A.

In some embodiments, each image output data can include one or more of 2D facial feature data, 2D geometric data, 2D facial feature relationship data, 3D landmark data, 3D geometric data, and/or 3D landmark relationship data. For example, the first image output data **941**A includes 2D facial feature data **942**A, 2D geometric data **943**A, 2D facial feature relationship data **944**A, 3D landmark data **945**A, 3D geometric data **946**A, and 3D landmark relationship data **947**A.

In some embodiments, multiple sets of image output data of a particular beauty target output data **940**A-N can be aggregated into a target output data or target representation. That is, each image output data (e.g., first image output data **941**A) can be aggregated such that the respective beauty target output data **940**A-N can represent a target face corresponding to the respective beauty target. For example, first image output data **941**A of first beauty target output data **940**A can be aggregated with Nth image output data of first beauty target output data **940**A, such that the aggregated output data (e.g., using averages) can represent the first target output.

In some embodiments, the 2D facial feature data **942**A can include data that represents one or more facial features of the human face (such as facial features described above). In some embodiments, the 2D facial feature data **942**A can correspond to a respective 2D image represented by 2D image data **932**A. For example, each 2D image (represented by 2D image data **932**A) can include a respective instance of 2D facial feature data **942**A. In another example, one or more facial features represented in a 2D image can be identified by respective 2D facial feature data. In some embodiments, for each of the facial features represented by the 2D facial feature data **942**A, the 2D facial feature data **942**A can identify one or more 2D points (e.g., pixels of the 2D image data **932**A) that represent a respective facial feature. For instance, the nose of can be represented by a single 2D point at the tip of the nose, or by multiple 2D points along the bridge of the nose, the tip of the nose, and/or outline of the nose. In some embodiments, the 2D facial feature data **942**A can include 2D coordinate data that represent the 2D points, such as x-coordinate and y-coordinate information identifying the one or more 2D points (e.g., pixels). In some embodiments, the 2D facial feature data **942**A can include textual identifiers of respective facial features represented by one or more 2D points (e.g., points X through Z represent the bridge of the nose). In some embodiments, the 2D facial feature data **942**A can include color data for the 2D points. For example, the color data for a 2D point can be expressed in values of the RGB model. It can be noted that points as described with respect to 2D information, such as 2D image data and 2D facial features data, 2D geometric data, and 2D facial feature relationship data can also be interchangeably described as pixels, herein, unless otherwise described. In some embodiments, the facial features represented by the 2D facial feature data **942**A can be referred to as "target 2D facial features" or "target facial features" herein.

In some embodiments, 2D geometric data **943**A can describe a facial feature represented by the 2D facial feature data **942**A. In some embodiments, 2D geometric data can refer to information related to 2D coordinate space (e.g., describing objects and shapes that exist in a flat plane, typically defined by two perpendicular axes). In some embodiments, the 2D geometric data **943**A can include one or more of 2D points (e.g., pixels), lines or curves, and/or shapes. In some embodiments, a 2D point can have 2D coordinates (e.g., x-, and y-coordinates). In some embodiments, the 2D point can identify a location where two or more lines or curves intersect. In some embodiments, a line can include a straight- or curved line and connect at least two 2D points. In some embodiments, shapes can include bounded areas, such as connecting lines (e.g., closed-loop lines, or enclosed shapes).

In some embodiments, the 2D geometric data **943**A can include data identifying a relationship between two or more 2D points of a facial feature represented by the 2D facial feature data **942**A (e.g., between two or more 2D points corresponding to the same facial feature). In some embodiments, the relationship between two or more 2D points can include one or more of distances, angles, positions, areas, or ratios.

In some embodiments, the 2D geometric data **943**A can include data identifying a line or curve between two or more 2D points, and the distance therebetween. For example, the 2D geometric data **943**A can include data identifying the length of an eyebrow that corresponds to a line or curve between two or more 2D points representing the eyebrow.

In some embodiments, the 2D geometric data **943**A can include data identifying two or more lines between three or more 2D points, and the ratio between the length of each line. For instance, the 2D geometric data can include data identifying a ratio between an eye height (represented as a first line between an eye apex and an eye bottom) and an eye width (represented as a second line between an inner eye corner and an outer eye corner).

In some embodiments, the 2D geometric data **943**A can include data identifying a curve between two or more 2D points, and a curvature radius of the curve. For example, the 2D geometric data **943**A can include data identifying the curvature of an eyebrow that corresponds to a curve between two or more 2D points representing the eyebrow.

In some embodiments, the 2D geometric data **943**A can include data identifying two or more lines between three or more 2D points, and the angle between the two or more lines. For example, the 2D geometric data **943**A can include data identifying a first line between a 2D point representing to the inner eye corner and a 2D point corresponding to the outer eye corner, a second (horizontal) line intersecting a 2D point corresponding to the center of the pupil, and an angle between the first line and the second line.

In some embodiments, the 2D geometric data **943**A can include data identifying two or more 2D points and a relative position of each of the two or more 2D points with respect to the group of two or more 2D points. For example, the 2D geometric data **943**A can include data identifying a first 2D point, a second 2D point, a third 2D point, and respective lengths and slopes of lines between each point (e.g., a length and slope of a line between the first and second 2D point, a length and slope of a line between the first and third 2D point, etc.). For instance, the 2D geometric data **943**A can include data identifying relative positional data for respective 2D points representing the inner corner of the eyebrow, the apex of the eyebrow, and the outer corner of the eyebrow, respectively.

In some embodiments, the 2D facial feature relationship data **944**A can include data identifying a relationship between 2D facial feature data **942**A of two or more facial features. In some embodiments, the 2D facial feature relationship data **944**A can include data identifying a relationship between 2D geometric data **943**A of two or more facial features. In some embodiments, the relationships between data corresponding to a first facial feature (e.g., first 2D facial feature data, and/or first 2D geometric data) and data corresponding to a second facial feature (e.g., second 2D facial feature data, and/or second 2D geometric data) can include one or more of distances between 2D points, angles, positions, or ratios of 2D information.

In some embodiments, the 2D facial feature relationship data **944**A can include data identifying a line or curve between one or more 2D points of a first facial feature represented in the 2D facial feature data **942**A, and one or more 2D points of a second facial feature represented in the 2D facial feature data **942**A. For example, the 2D facial feature relationship data **944**A can include data identifying a distance between one or more points representing the left eye and one or more points representing the right eye.

In some embodiments, the 2D facial feature relationship data **944**A can include data identifying a first line between two or more 2D points of a first facial feature and a second line between two or more 2D points of a second facial feature, and the angle between the first line and the second line. For example, the 2D facial feature relationship data **944**A can include data identifying an angle between a horizontal line between 2D points representing the right and left pupils, and a right eye line between 2D points representing the inner corner of the right eye and the outer corner of the right eye.

In some embodiments, the 2D facial feature relationship data **944**A can include data identifying a first measurement (e.g., size, length, depth width, area, etc.) corresponding to a first facial feature (represented by one or more 2D points) and a second measurement corresponding to a second facial feature (represented by one or more 2D points), and a ratio between the first measurement and the second measurement. For example, the 2D facial feature relationship data **944**A can include data identifying a ratio between an eye size (represented by one or more 2D points representing the eye) and a mouth size (represented by one or more 2D points representing the mouth).

Additional details regarding 2D facial feature data, 2D geometric data, and 2D facial feature relationship data are described with reference to FIGS. **5**A-B.

In some embodiments, the 3D landmark data **945**A can include data that represents one or more 3D landmarks corresponding to one or more facial features of the human face (e.g., represented by 2D facial feature data **942**A). In some embodiments, 3D landmark data can correspond to associated 2D facial feature data (e.g., represent the same facial feature). In some embodiments, 3D landmark data **945**A can identify one or more 3D points (e.g., vertices of the 3D model data **933**A) that represent a respective facial feature represented by the 2D facial feature data **942**A. For example, the nose of a subject can be represented by a single 3D point (and corresponding 2D point of the 2D facial feature data **942**A) at the tip of the nose, or by multiple 3D points (and corresponding 2D points of the 2D facial feature data **942**A) along the bridge of the nose, the tip of the nose, and/or outline of the nose.

In some embodiments, the 3D landmark data **945**A can include 3D coordinate data that represents the 3D points, such as x-coordinate, y-coordinate, and z-coordinate information identifying the one or more 3D points (e.g., vertices) in three-dimensional space. In some embodiments, the 3D landmark data **945**A can include textual identifiers of respective facial features represented by one or more 3D points. For example, a 3D landmark that represents a nose can include or be associated with a textual identifier, "nose." In some embodiments, the 3D landmarks identified by the 3D landmark data that correspond to facial features represented by the 2D facial feature data **942**A can be referred to as "target 3D landmarks" or "3D landmarks" herein.

In some embodiments, the 3D landmark data **945**A can correspond to a respective 3D model represented by a 3D model data. For example, each 3D model can include a respective instance of 3D landmark data **945**A.

In some embodiments, 3D geometric data **946**A can describe a 3D landmark represented by the 3D landmark data **945**A. In some embodiments, the 3D geometric data **946**A can include one or more of vertices (e.g., 3D points), edges, and/or faces. In some embodiments, vertices (e.g., nodes or points) can include 3D points of a 3D model represented by 3D landmark data **945**A. A vertex can have 3D coordinates (e.g., x-, y-, and z-coordinates). The vertex can identify a location where one or more edges intersect. In some embodiments, an edge can include a line, such as a straight line and connect at least two vertices. In some embodiments, faces can include surfaces, such as planar surfaces, connecting edges (e.g., closed-loop edges).

In some embodiments, the 3D geometric data **946**A can include data identifying a relationship between two or more 3D points of a facial feature represented by the 3D landmark data **945**A (e.g., between two or more 3D points corresponding to the same facial feature). In some embodiments, the relationship between two or more 2D points can include one or more of distances, angles, positions, areas, or ratios.

In some embodiments, the 3D geometric data **946**A can include data identifying a line or curve between two or more 3D points, and the distance therebetween. For example, the 3D geometric data **946**A can include data identifying the length of an eyebrow that corresponds to a line or curve between two or more 3D points representing the eyebrow.

In some embodiments, the 3D geometric data **946**A can include data identifying two or more lines between three or more 3D points, and the ratio between the length (e.g., magnitude) of each line. For example, the 3D geometric data can include data identifying a ratio between a 3D eye height (represented as a first line between an eye apex and an eye bottom) and a 3D eye width (represented as a second line between an inner eye corner and an outer eye corner).

In some embodiments, the 3D geometric data **946**A can include data identifying a curve between two or more 3D points, and a curvature radius of the curve. For example, the 3D geometric data **946**A can include data identifying the curvature of an eyebrow that corresponds to a curve between two or more 3D points representing the eyebrow.

In some embodiments, the 3D geometric data **946**A can include data identifying two or more lines between three or more 3D points, and the angle between the two or more lines. For example, the 3D geometric data **946**A can include data identifying a first line between a 3D point corresponding to the inner eye corner and a 3D point corresponding to the outer eye corner, and a second (horizontal) line intersecting a 2D point corresponding to the center of the pupil, and an angle between the first line and the second line.

In some embodiments, the 3D geometric data **946**A can include data identifying two or more 3D points and a relative position of each of the two or more 3D points with respect to the group of two or more 3D points. For example, the 3D geometric data **946**A can include data identifying a first 3D point, a second 3D point, a third 3D point, and respective lengths and slopes of lines between each point (e.g., a length and slope of a line between the first and second 3D point, a length and slope of a line between the first and third 3D point, etc.). For instance, the 3D geometric data **946**A can include data identifying relative positional data for respective 3D points representing the inner eyebrow corner, the eyebrow apex, and the outer eyebrow corner, respectively.

In some embodiments, the 3D landmark relationship data **947**A can include data identifying a relationship between 3D landmark data **945**A corresponding to two or more respective facial features. In some embodiments, the 3D landmark relationship data **947**A can include data identifying a relationship between 3D geometric data **946**A corresponding to two or more facial features. In some embodiments, the relationships between data corresponding to a first facial feature (e.g., 3D landmark data **945**A and/or 3D geometric data **946**A) and data corresponding to a second facial feature (e.g., second 3D landmark data and/or 3D geometric data) can include one or more of distances, angles, positions, areas, or ratios of 3D information.

In some embodiments, the 3D landmark relationship data **947**A can include data identifying a line or curve between one or more 3D points corresponding to a first facial feature and one or more 3D points corresponding to a second facial feature. For example, the 3D landmark relationship data **947**A can include data identifying a distance between one or more points representing the left eye and one or more points representing the right eye (e.g., the distance between the left and right eye).

In some embodiments, the 3D landmark relationship data **947**A can include data identifying a first line between two or more 3D points of a first facial feature and a second line between two or more 3D points of a second facial feature, and an angle(s) between the first line and the second line. For example, the 3D landmark relationship data **947**A can include data identifying angle(s) between a horizontal plane that intersects the 3D points representing the right and left pupils, and a right eye line between 3D points representing the inner corner of the right eye and the outer corner of the right eye.

In some embodiments, the 3D landmark relationship data **947**A can include data identifying a first measurement (e.g., size, length, depth, width, area, etc.) corresponding to a first facial feature (corresponding to one or more 3D points) and a second measurement corresponding to a second facial feature (corresponding to one or more 3D points), and a ratio between the first measurement and the second measurement. For example, the 3D landmark relationship data **947**A can include data identifying a ratio between an eye size (represented by one or more 3D points representing the eye) and a mouth size (represented by one or more 3D points representing the mouth).

Additional details regarding the 3D landmark data **945**A, 3D geometric data **946**A, and 3D landmark relationship data **947**A are described with reference to FIGS. **5**A-B.

In some embodiments, variation information **940**X can include information identifying one or more variations (e.g., differences) between a target face corresponding to a particular beauty target and a target face corresponding non-beauty target. As described above, a target face corresponding to the first beauty target can be represented by aggregating some or all the image output data of the first beauty target output data **940**A (e.g., aggregating the first image output data **941**A with Nth image output data, etc.). Thus, in some embodiments, variation information **940**X can include information identifying differences between aggregated image output data (e.g., first image output data **941**A through Nth image output data, etc.) of the first beauty target output data **940**A, and aggregated image output data (e.g., first image output data **941**A through Nth image output data, etc.) of the non-beauty target output data **940**N.

In some embodiments, variation information **940**X can be generated for each pairing between a respective beauty target and a non-beauty target. For example, the variation information **940**X can be generated to include information identifying differences between first beauty target output data **940**A (e.g., representing a first beauty target face) and non-beauty target output data **940**N (e.g., representing a non-beauty target face). In another example, the variation information **940**X can be generated to include information identifying differences between m-th beauty target output data **940**M (e.g., representing an m-th beauty target face) and non-beauty target output data **940**N (e.g., representing a non-beauty target face).

In some embodiments, variation information **940**X can include information identifying differences between one or more elements of first beauty target output data **940**A (aggregated or non-aggregated) and corresponding elements of non-beauty target output data **940**N. For example, variation information **940**X can include information identifying a difference between aggregated first beauty 2D facial feature data (e.g., similar to, or including 2D facial feature data **942**A of the first beauty target output data **940**A) and aggregated non-beauty 2D facial feature data (e.g., similar to, or including 2D facial feature data of the non-beauty target output data **940**N (not illustrated)). In another example, variation information **940**X can include information identifying a difference between first beauty 3D landmark data (e.g., similar to, or including 3D landmark data

945A of the first beauty target output data 940A), and non-beauty 3D landmark data (e.g., similar to, or including 3D landmark data of the non-beauty target output data 940N (not illustrated)).

In some embodiments, variation information 940X can include data representing a magnitude difference (e.g., such as a difference in x-, y-, z-coordinates of a particular facial feature of a beauty target face and a non-beauty target face respectively). In some embodiments, data identifying a magnitude difference can be a difference between elements of first beauty target output data 940A and corresponding elements of non-beauty target output data 940N. For example, a magnitude difference can be a difference in a width (e.g., magnitude) of a particular facial feature corresponding to a first beauty target output data 940A representing a first beauty target, in comparison to a width of the particular facial feature corresponding to the non-beauty target. For instance, variation information 940X may include data that indicates that a 3D width of the beauty target eye is three millimeters greater than the width of the non-beauty target eye.

In some embodiments, variation information 940X can include data representing a ratio difference (e.g., such as a difference in a size of a particular facial feature of a beauty target face and a non-beauty target face respectively). In some embodiments, data identifying a ratio difference can be a difference (e.g., a difference in size, etc.) between elements of first beauty target output data 940A and corresponding elements of non-beauty target output data 940N (e.g., a beauty target face and a non-beauty target face). For example, a ratio difference can be a difference between a beauty target ratio corresponding to a particular facial feature of the beauty target face and a non-beauty target ratio corresponding the particular facial feature of the non-beauty target face. For example, variation information 940X can include data that indicates an eye-to-nose size ratio of the first beauty target is 1:1.2, and an eye-to-nose size ratio of the non-beauty target is, for example, 1:1.3. The data included in the variation information can indicate that the non-beauty target ratio is 1.083 times greater (e.g., 1.3/1.2) than the beauty target ratio.

In some embodiments, variation information 940X can be generated as a target output 940 by training set generator 131 based the beauty target indication 930X. In some embodiments, the indication of a beauty target indication 930X can indicate to generate variation information 940X between a particular beauty target (e.g., first beauty target output data 940A) and non-beauty target output data 940N. As described above, beauty target indication 930X can include an indication of a beauty target corresponding to a particular beauty target (e.g., beauty target input data 930A-M). At inference, variation information 940X can be generated based on the selection information indicated in beauty target indication 930X.

FIG. 10 is an example system for training a machine learning model using information pertaining to various beauty targets, in accordance with embodiments of the disclosure. System 1000 illustrates a training set generator 131, training inputs 1030, generative machine learning model 170 with model parameters 1061, training outputs 1040, and evaluation module 1050 with evaluation metric 1051. System 1000 can include similar components as system 100, as described in FIG. 1. Components described with reference to system 100 of FIG. 1 can be used to describe system 1000 of FIG. 10. In some embodiments, the parameter modification data 1053 can be generated by evaluation module 1050 based on the evaluation metric 1051 and can be used as an input to generative machine learning model 170 and/or to alter one or more of the model parameters 1061. It can be noted that system 1000 can also be used in inference to, for example, generate new facial feature information.

In some embodiments, generative machine learning model 170 is a generative machine learning model. In some embodiments, generative machine learning model 170 is trained using unsupervised (e.g., learn patterns and information from data without explicit labeled output) or semi-supervised machine learning (e.g., where some of the input and/or output data is labeled (e.g., supervised) and some of the input and/or output data is not labeled (e.g., unsupervised)). In some embodiments, the generative machine learning model 170 can be trained to generate new data, such as computer-derived features, such as computer-derived 2D facial feature data, computer-derived 2D geometric data, computer-derived 2D facial feature relationship data, computer-derived 3D landmark data, computer-derived 3D geometric data, and computer-derived 3D landmark data. A computer-derived feature can refer to attributes or information, often about an individual's face, that is extracted, analyzed, recognized by a computer (e.g., processing device implementing digital image processing). In some embodiments, a computer-derived feature may be a feature that is generated by a machine learning model. In some embodiments, the computer-derived features may be generated by a machine learning model without direct human intervention. In some embodiments, the computer derived features can be new data and can include previously unknown features (e.g., 2D facial feature data, 3D landmark data, etc.) or unknown relationships between features (e.g., 2D facial feature relationship data, 3D landmark relationship data, etc.). It can be noted that although generative machine learning model 170 is described as a generative machine learning model, in some embodiments a discriminative machine learning model may be implemented.

In some embodiments, training inputs 1030 can be used as input to a machine learning model, such as generative machine learning model 170. In some embodiments, the training input 1030 can include beauty target data 1030A. In some embodiments, beauty target data 1030A can include one or more of 2D image data 1031A and 3D model data 1032A. 2D image data 1031A and 3D model data 1032A can be the same as, or similar to 2D image data 932A and 3D model data 933A respectively, as described above with reference to FIG. 9. As described above, in some embodiments, 3D model data 1032A can be generated from 2D image data 1031A that represents one or more 2D images. In some embodiments, 3D model data 1032A can be generated from 2D image data 1031A. While not illustrated here, 2D image data 1031A and 3D model data 1032A can represent multiple 2D images and 3D models, respectively, that can be used as input to the generative machine learning model 170. For example, 2D image data 1031A that represents multiple 2D images, and 3D model data 1032A that represents multiple 3D models generated using the 2D images can be used as beauty target data 1030A.

In some embodiments, the 2D image data 1031A and the 3D model data 1032A can be associated with labeled data. In some embodiments, the 2D image data 1031A and the 3D model data 1032A can be labeled by one or more human evaluators. For example, the 2D image data and 3D model data can be associated with one or more respective labels identifying one or more of 2D facial feature data, 2D geometric data, 2D facial feature relationships data, 3D landmark data, 3D geometric data, and 3D landmark data. In some embodiments, the labeled data can be used as evaluation metrics **1051** and compared to training outputs **1040**.

In some embodiments, the 2D image data **1031**A and the 3D model data **1032**A can be preprocessed prior to being input to the generative machine learning model **170**. In some embodiments, after the 3D model data **1032**A is generated from the 2D image data **1031**A, information from the 3D model data **1032**A is used to add visual augmentations to the 2D image data **1031**A (e.g., used to enhance the 2D image data **1031**A). For example, information in the 3D model data **1032**A associated with an outline of the eye, such as the curve of an eyelid, can be used to augment the 2D image data **1031**A or 3D model data **1031**A. In another example, information in the 3D model data **1032**A associated with the shape of the face or shape of facial features (e.g., represented by 2D facial feature data **1040**A) can be used to crop the 2D image (e.g., modify the 2D image data **1031**A) to the shape of the face, or a particular facial feature. In some embodiments, a generative machine learning model (e.g., VLM) or discriminative machine learning model is used to determine whether the 2D image data **1031**A or the 3D model data **1032**A is to be included in model training data. In some embodiments, a human evaluator can manually perform any combination of these and other preprocessing techniques on the 2D image data **1031**A and the 3D model data **1032**A before the 2D image data **1031**A and/or 3D model data **1032**A are input into the generative machine learning model **170**.

In some embodiments, the generative machine learning model **170** can be trained to generate training outputs **1040** based on one or more of the training inputs **1030**. In some embodiments, training outputs **1040** include one or more of 2D facial feature data **1040**A, 2D geometric data **1040**B, 2D facial feature relationship data **1040**C, 3D landmark data **1040**D, 3D geometric data **1040**E, and 3D landmark relationship data **1040**F. In some embodiments, the generative machine learning model **170** can be trained to generate some or all of the training outputs **1040** for each instance of beauty target data **1030**A. For instance, the generative machine learning model **170** can be trained to generate the 2D facial feature data **1040**A for the training input of 2D image data **1031**A. In some embodiments, multiple sets of 2D image data **1031**A can be used as input to the generative machine learning model **170**, and the generative machine learning model **170** can generate distinct outputs (e.g., training outputs **1040**) for each distinct input of 2D image data **1031**A. For example, 2D image data **1031**A that represents a first 2D image and second 2D image data representing a second 2D image can be used as input for the generative machine learning model **170**. The generative machine learning model **170** can generate a first 2D facial feature data (e.g., 2D facial feature data **1040**A) corresponding to the first 2D image (e.g., represented by 2D image data **1031**A) and a second 2D facial feature data corresponding to the second 2D image.

In some embodiments, the generative machine learning model **170** can include one or more of the model parameters **1061**. The values of the model parameters **1061** can affect how the beauty target data **1030**A generates the training outputs **1040**. In some embodiments, as described above, the model parameters **1061** can be adjusted to adjust how the generative machine learning model **170** generates the training outputs **1040** from the training input **1030**.

In some embodiments, the model parameters **1061** can be adjusted based on parameter modification data **1053** generated by evaluation module **1050**. In some embodiments, evaluation module **1050** can receive the training outputs **1040** and determine whether the training outputs **1040** satisfy one or more of the evaluation metrics **1051**.

In some embodiments, the evaluation metrics **1051** can include one of one or more ground truths corresponding to respective outputs (e.g., training outputs **1040**), or training rule data identifying correct answers corresponding to the training outputs, and/or threshold data corresponding to the training outputs **1040**. In some embodiments, the evaluation module **1050** can determine whether a particular training output represents a respective ground truth of the evaluation metrics **1051**.

In some embodiments, the evaluation metrics **1051** can include a beauty threshold that corresponds to one or more of the training outputs **1040** (e.g., a 2D facial feature data beauty threshold, a 2D geometric data beauty threshold, etc.). For example, the beauty thresholds can be derived from a beauty target (e.g., a first beauty target as described with reference to FIG. **9**). The training outputs **1040** can be compared to respective beauty thresholds.

In some embodiments, the evaluation module **1050** can perform reinforcement learning by rewarding the generative machine learning model **170** when one or more of the training outputs **1040** satisfies one or more of the corresponding evaluation metrics (e.g., evaluation metrics **1051**), or penalizing the model when one or more of the training outputs **1040** does not satisfy one or more of the evaluation metrics **1051**.

In some embodiments, evaluation metric **1051** can include a training rule represented by training rule data. In some embodiments, training rule data can include rules for the training outputs **1040**. For example, training rule data can require that a first portion of a facial feature and a second portion of a facial feature have a minimum correspondence value. That is, that the first portion of a facial feature (e.g., a computer-defined facial feature) is sufficiently related to a second portion of the facial feature. For instance, if the generative machine learning model **170** identifies a facial feature (e.g., a computer derived facial feature represented by 2D facial feature data **1040**A) as including the human-defined facial features of the "nose" and "mouth," training rule data from the evaluation metric **1051** can determine whether the first portion (e.g., the nose) and the second portion (e.g., the mouth) are sufficiently related (e.g., using metrics of similarity, proximity, shared 2D points and/or 3D landmarks, etc.).

In some embodiments, a portion of the processes of the evaluation module **1050** can be performed by a human reviewer. In some embodiments, the evaluation metric **1051** can include or reflect a human-derived metric. For example, one or more human evaluators can determine whether a particular training output matches a respective ground truth. For example, a human reviewer can indicate whether one or more of the training outputs **1040** satisfies a beauty threshold corresponding to a particular beauty target. In other embodiments, the evaluation metric **1051** can include a computer-derived metric.

In some embodiments, a portion of the processes of the evaluation module **1050** can be performed by users of a machine learning model **160**. That is, users of the machine learning model **160** can provide feedback explicitly as prompted, or implicitly, by making one or more selections for beauty targets (e.g., with beauty target indication **930**X), and the feedback received from users of the machine learning model **160** can be used to further train the generative model **170**. In some embodiments, the generative machine learning model **170** is a model used to supplement or provide data to the machine learning model **160** (e.g., training data).

That is, users of the machine learning model **160** do not directly interact with or use the generative machine learning model **170**. However, the data collected from users using the machine learning model **160** can be used to improve the generative machine learning model **170**. For example, if multiple users of the machine learning model **160** consistently select a certain beauty target (reflected by beauty target indication **930**X), the selected beauty target can be used as a reference to further train the generative machine learning model **170** (e.g., the certain beauty target can be used as an input to generate refinement training data for the generative machine learning model **170**).

In some embodiments, the evaluation module **1050** can generate parameter modification data **1053** based on whether one or more evaluation metrics **1051** were satisfied by the training outputs **1040**. In some embodiments, if the training outputs **1040** do not satisfy one or more of the evaluation metrics **1051**, the parameter modification data **1053** can reflect that the particular training output does not satisfy the evaluation metric **1051**. In some embodiments, the parameter modification data **1053** can identify information to change one or more of the model parameters **1061** of generative machine learning model **170**. In some embodiments, the parameter modification data **1053** can include new, or modified values for model parameters **1061**. For example, parameter modification data **1053** can include replacement values for the model parameters **1061**, or relative changes to values of the model parameters **1061**. For instance, if a particular model parameter has a value of "X," the parameter modification data **1053** can indicate "+Y," such that once integrated, the particular model parameter can have a value of "X+Y."

FIG. **11** is a block diagram of an example conversion system architecture **1100** for providing conversion of 2D image data corresponding to a 2D image to a corresponding 3D model, in accordance with embodiments of the disclosure. In some embodiments, conversion system **1120** can include one or more of preprocessing engine **1106**, conversion engine **1108**, and/or postprocessing engine **1110**. In some embodiments, conversion system **1120** can use the 2D image data **1103** corresponding to image **1102** to generate the 3D model data **1116** of a 3D model **1114**.

In some embodiments, image **1102** is a 2D image that is represented by 2D image data **1103**. As described above, in some embodiments, image **1102** can include an image of a subject's face or a part of the subject's face (e.g., an image of a subject's eye area).

Image **1102** may depict one or more facial features, such as facial features **1104**A-N of the subject's face. As described above, a facial feature can refer to a physical characteristic or element that is part of a human face. Examples of facial features that may be depicted in image **1102** include eyebrow features (e.g., inner eyebrow, eyebrow apex, center eyebrow, outer eyebrow) represented by facial feature **1104**A, eye features (e.g., pupil, inner eye, outer eye, upper lid, tightline) represented by facial feature **1104**B, nose features (e.g., bridge, nostrils) represented by facial feature **1104**C, lip features (e.g., upper lip, lower lip) represented by facial feature **1104**N, mouth features (e.g., corner of the mouth), and so forth.

In some embodiments and as noted above, conversion system **1120** can use the 2D image data **1103** corresponding to the image **1102** as input to the conversion system **1120**.

In some embodiments and as noted above, conversion system **1120** can use the 2D image data **1103** of image **1102** to generate information corresponding to 3D model **1114** (e.g., 3D model data **1116**). As described above, 3D model **1114** can refer to a three-dimensional digital representation of a scene or object. The 3D model can be represented by 3D model data **1116**. As described above, in some embodiments, one or more of vertices, edges and faces can define the geometry of a 3D model **1114**.

As described above, in some embodiments, 3D model data **1116** of the 3D model **1114** includes material information that can influence the appearance of the 3D model **1114** at rendering (e.g., how light reflects from the material).

In some embodiments, the 3D model data **1116** of the 3D model **1114** can include landmark data, such as 3D landmark data **1112**. In some embodiments, one or more landmarks can be represented by 3D landmark data **1112**. As described above, a landmark can be represented by the grouping of points of the 3D model **1114** that represent the right eye, the inner corner of the eyes, the bridge of the nose, a centerline of a face, or some other facial feature.

In some embodiments, 3D landmark data **1112** can include information identifying one or more points of the 3D model **1114** (e.g., specific grouping of points and/or 3D coordinate data of the points) that correspond to a feature, such as a facial feature. In some embodiments, 3D landmark data **1112** can include information identifying the relationship between one or more points of a landmark. To identify the relationship between the one or more points of a landmark, the 3D landmark data **1112** can include information identifying one or more of edges, faces, geometric data, such as length, height, and depth, and/or ratios of geometric data. To identify the relationship between the one or more points of a landmark, the 3D landmark data **1112** can include one or more of absolute or relative values (e.g., deviations from average or template values). As described above, in some embodiments, 3D landmark data **1112** can include information identifying relationships between multiple landmarks.

In some embodiments, preprocessing engine **1106** of conversion system **1120** can perform one or more preprocessing operations on 2D image data **1103**. In some embodiments, preprocessing engine can clean, transform, and/or organize the 2D image data **1103** of image **1102** in a manner suitable to be received by conversion engine **1108** (also referred to as "preprocessed 2D image data" herein). For example, preprocessing engine **1106** may scale or crop the image **1102** and generate corresponding 2D image data (e.g., preprocessed image data, such as 2D image data **1103**). In some embodiments, preprocessing engine **1106** can convert image **1102** from an RGB color space to a grayscale color space, or vice versa. In some embodiments, preprocessing engine **1106** can convert image **1102** to a common or preferred format (e.g., JPEG).

In some embodiments, preprocessing engine **1106** may perform preprocessing with one or more machine learning (ML) models. For example, a machine learning (ML) model may be implemented to identify one or more facial features, such as facial features **1104**A-N (which may be added to 2D image data **1103** (e.g., metadata) of image **1102**). In another example, an ML model can be used to enhance contrast or resolution of image **1102**. In some embodiments, an ML model can be used to remove objects or a background element from image **1102**. For instance, an ML model can be used to remove glasses from a subject's face and fill the area where the glasses were removed with color and/or texture that is similar or that appears seamless with the surrounding area.

In an embodiment where conversion engine **1108** includes an ML model as described below, preprocessing engine **1106** may select or exclude various input images (e.g., image **1102**) as part of a training procedure to achieve a desired effect in training the ML model of conversion engine **1108**. In an embodiment, preprocessing engine **1106** may not be implemented, and 2D image data **1103** (e.g., raw 2D image data) of image **1102** may be provided as input to conversion engine **1108**.

In some embodiments, conversion engine **1108** uses the 2D image data **1103** (e.g., raw, or preprocessed) to generate a 3D model **1114** (e.g., 3D model data **1116** of 3D model **1114**). In some embodiments, conversion engine **1108** can generate the 3D model **1114** with or without postprocessing engine **1110**.

In some embodiments, conversion engine **1108** can implement one or more techniques to convert the 2D image data **1103** to a 3D model **1114**. In some embodiments, conversion engine **1108** may include an ML technique (e.g., statistical learning, deep learning, reinforcement learning, etc.) to convert the 2D image data **1103** into a 3D model **1114**. For example, conversion engine **1108** may include a neural radiance field (NeRF) ML model. In another example, conversion engine **1108** may include an ML model based on differential rendering or inverse rendering techniques. ML models of conversion engine **1108** may operate in a training mode or an inference mode. In a training mode, 2D and/or 3D training data may be provided as input and/or output of the ML model for supervised or unsupervised training. In an inference mode, 2D image data **1103** may be provided as input to the ML model for generation of 3D model data **1116** of 3D model **1114** in accordance with previous training.

In some embodiments, conversion engine **1108** may include a principal component analysis (PCA) model (further described below with reference to FIGS. **13-14**) to convert the 2D image data **1103** to a 3D model **1114**.

In some embodiments, conversion engine **1108** may include a non-machine learning technique for converting the 2D image data **1103** into 3D model **1114**. For example, conversion engine **1108** may include parametric techniques based on various mathematical or physical principals, heuristics, or similar. In some embodiments, conversion engine **1108** may include an ML module and/or a non-machine learning module for converting the 2D image data **1103** into 3D model data **1116** of 3D model **1114**.

In some embodiments, postprocessing engine **1110** of conversion system **1120** can perform one or more postprocessing operations on 3D model data **1116** (e.g., also referred to as "postprocessed 3D model data" herein). In some embodiments, postprocessing engine **1110** can perform further analysis, refinement, transformations and/or other modifications of 3D model data **1116** received from conversion engine **1108**. For example, postprocessing engine **1110** may generate a set of 3D landmark data of one or more landmarks corresponding to facial features by grouping particular vertices of the 3D model **1114** that represent respective landmarks. In another example, postprocessing engine **1110** can remove or modify the 3D model data **1116**. In some embodiments, postprocessing engine can emphasize particular landmarks (e.g., weighting or PCA techniques) and/or define particular landmarks and/or remove particular landmarks and/or de-emphasize particular landmarks. In some embodiments, postprocessing engine **1110** is not implemented, and thus 3D landmark data **1112** can be generated by conversion engine **1108**.

FIG. **12** depicts an example of a 3D model **1200** of a face of a subject, in accordance with embodiments of the disclosure. In some embodiments, 3D model **1200** (e.g., rendered 3D model) may, for the sake of illustration and not limitation, correspond to image **1102** of FIG. **11**.

3D model data **1116** may be used to generate, render, or modify the 3D model **1200** to represent the subject's face. Landmarks **1202**A-N of 3D model **1200** may correspond to and be represented by 3D landmark data **1112** of FIG. **11**. As noted herein, landmarks can correspond to features such as facial features. For example, landmark **1202**F can correspond to the bridge of the nose. Landmark **1202**C can correspond to the lash line of the left eye. Landmark **1202**D can correspond to the center point of the pupil of the left eye, and so forth.

In some embodiments, 3D model **1200** may correspond to various types of 3D modeling techniques. For example, in an embodiment, 3D model **1200** may be a mathematical model. In some embodiments, a mathematical model can include a parametric model where landmarks **1202**A-N and other 3D features may be represented by mathematical functions such as one or more of points, lines, arcs, Bezier curves, functional manifolds, and so on. In another embodiment, 3D model **1200** may be a mesh model, a point cloud model, or similar model comprising multiple objects such as vertices, lines, and faces to represent the subject's face. Landmarks **1202**A-N may correspond to one or more vertices, one or more lines, one or more faces, or sets thereof. In some embodiments, landmarks **1202**A-N may share or overlap geometry. For example, two overlapping landmarks may share vertices, lines, etc. In another embodiment, 3D model **1200** may be an ML model, such as a neural radiance field model trained to produce 2D views of the subject's face from multiple positions in 3D space. Landmarks **1202**A-N may correspond to weights, convolutional filters, or other aspects of the ML model (which can be captured in corresponding 3D model data). In another embodiment, 3D model **1200** may comprise multiple model representations, such as a parametric representation combined with a mesh representation or similar.

In an embodiment, 3D model **1200** may be a morphological model. A morphological model can represent the shape and structure of objects (e.g., human faces) using morphological data. In some embodiments, morphological data can describe the form and structural relationships between geometry (e.g., vertices, lines, planes and/or landmarks) of the model and enables manipulation of the geometry based on those relationships. In some embodiments, a morphological model may include a template model (e.g., 3D template model) of a human face. The template model may be initialized with template 3D model values (e.g., template landmark data) reflecting average values (e.g., average positions, sizes, colors, etc.) for an object, such as a human face. The template 3D model values may be derived from a representative collection of objects, such as human faces or features thereof. In some embodiments, the template model can be used as a reference model that can be compared to values representing a subject's unique face. In some embodiments, the comparison can generate difference information (e.g., metric) reflecting differences (e.g., deltas or deviations) between the template 3D model values, and in particular the template landmark data, and values representing corresponding points and/or facial features of the subject's face. The difference information can be stored as part of 3D landmark data **1112**. To generate the 3D model of the subject's face, conversion system **1120** may adjust the template model based on the difference information corresponding to a particular subject, which can contribute to computational efficiency in generating a 3D model. In some embodiments, a morphological model can be used with a PCA model to generate a 3D model, as described further below.

FIG. **13**A is an example pipeline block diagram of an architecture **1300** for a principal component analysis (PCA) model generation architecture to train a PCA model of principal components, in accordance with some embodiments. FIG. **13**B is an example pipeline block diagram of a 3D model generation architecture **1350** for generating a 3D model from 2D image data using a trained PCA model and a morphological model.

In some embodiments, PCA can refer to a technique that can be used to transform a dataset into a new set of dimensions (principal components). The principal components may include linear combinations of original data features in the dataset. The combinations can be derived to capture variance (e.g., maximum variance) in the dataset. The principal components may be orthogonal (e.g., uncorrelated) and ranked according to the variance. In some embodiments, the resulting principal components can form, at least in part, a trained PCA model based on the dataset (the training data). The trained PCA model can be used to characterize or transform other data into respective principal components by projecting the other data onto the principal components of the trained PCA model. In some embodiments, PCA techniques can be used to transform features (e.g., facial features) of the original data, such as 2D image data, into a new set of principal components, which may be used to generate the 3D models and perform other analyses on the 2D image data.

Referring to FIG. **13**A, architecture **1300** includes 2D image dataset **1302**, principal component generation engine **1311**, PCA model postprocessing engine **1312**, and PCA model **1322**. In some embodiments, 2D image dataset **1302** includes one or more 2D image data **1304**A-N each corresponding to a respective 2D image. In some embodiments, each of 2D image data **1304**A-N may correspond to a 2D image of a human face, such as image **1102** of FIG. **11**. In some embodiments, 2D image dataset **1302** may be derived from a training set of 2D images of human faces, which may be manually or automatically curated. In some embodiments, and as described with reference to FIG. **11**, the data of 2D image dataset **1302** may be preprocessed with various techniques to change resolutions, adjust color depths, prune undesirable image data, or similar.

In some embodiments, PCA model **1322** includes one or more principal components **1324**A-N each associated with a feature, such as 2D facial feature. In some embodiments, a principal component of principal components **1324**A-N may correspond to a human-derived facial feature, such as eye color, inner eye distance, eye angle, jaw shape, or similar. As described above, a human-derived facial feature can refer to a physical characteristic or element that is part of a human face and that naturally occurs on an individual's face and can be assessed or recognized by a human eye (e.g., human perception). In some embodiments, a principal component of principal components **1324**A-N may correspond to a computer-derived facial feature, such as a correlation between multiple human-derived facial features (e.g., a correlation between inner eye distance and jaw shape), non-human derived facial features, or a combination thereof.

In some embodiments, a principal component of principal components **1324**A-N may correspond to a computer-derived facial feature. A computer-derived facial feature can refer to attributes or information about an individual's face that is extracted, analyzed, or recognized by a computer (e.g., processing device implementing digital image processing). A computer-derived facial feature may not be assessed or recognized by a human eye. In some embodiments, the computer-derived facial feature is generated by an algorithm (e.g., PCA model, machine learning model, etc.). In some embodiments, the computer-derived facial feature is generated by an algorithm without human intervention. In some embodiments, the principal components of a trained PCA model **1322** (including principal components corresponding to human-derived and/or computer-derived features) may represent an average or template set of facial features based on the variance of facial features present in 2D image dataset **1302**. A difference (e.g., difference metric) between an individual subject's facial feature and the principal component template can thus be expressed as a weight (e.g., a multiplier or a difference) of the corresponding principal component (e.g., the facial features is stronger/weaker than average as indicated by a larger/smaller weight or a positive/negative weight), as described below with reference to FIG. **13**B.

In some embodiments, PCA model **1322** can be generated or trained by one or more of principal component generation engine **1311** or PCA model postprocessing engine **1312**. In some embodiments, principal components **1324**A-N may be derived from 2D image dataset **1302** using PCA training techniques. In some embodiments, 2D image dataset **1302** may be modified to elicit select principal components. In some embodiments, 2D image dataset **1302** may be modified to elicit principal components corresponding to human-derived facial features. For example, a dataset representing human faces may be manually or automatically chosen (e.g., by preprocessing engine **1306**) to encourage identification of specific human-derived facial features. A feedback loop may be used with multiple generation cycles in principal component generation engine **1311** to refine the dataset and/or resulting principal components. In some embodiments, the principal components may be selected, modified, pruned, or a combination thereof to retain principal components corresponding to one or criteria such as human-derived facial features. For example, principal components corresponding to computer-derived features may be manually or automatically removed (e.g., by PCA model postprocessing engine **1312** or postprocessing engine **1310**) to obtain PCA model **1322**. In another example, principal components associated with different 2D image datasets (e.g., 2D image dataset **1302**) may be combined to form a composite PCA model (e.g., a PCA model **1322**) corresponding to human-derived facial features, where principal components **1324**A-N of the composite model may not necessarily be orthogonal (e.g., uncorrelated) to each other as would be expected in a set of principal components derived from a single dataset.

Referring to FIG. **13**B, 3D model generation architecture **1350** includes 2D image data **1352**, PCA engine **1360**, PCA data **1372**, morphological model generation engine **1380**, template morphological model **1382**, and 3D model **1390**. In some embodiments, 2D image data **1352** may correspond to an image of a scene or object, such as a subject's face (e.g., image **1102** of FIG. **11**). In some embodiments, PCA engine **1360** includes PCA model **1322** of FIG. **13**A, with each principal component **1324**A-N corresponding to a facial feature as previously described. In some embodiments, PCA engine **1360** can be used to transform or project the 2D image data **1352** into the facial feature eigenspace of PCA model **1322** (or non-eigenspace for a composite PCA model, such as a PCA model **1322** as previously described) to generate PCA data **1372**. PCA engine **1360** may perform a set of operations (e.g., a set of dot product operations) to perform the projection. In some embodiments, PCA engine **1360** may correspond to conversion system **1120** of FIG. **11**.

In some embodiments, PCA data **1372** may include difference metrics **1374**A-N (also referred to as "difference information" herein) representing the projection of 2D image data **1352** over each of principal components **1324**A-N. A difference metric of difference metrics **1374**A-N may correspond to a deviation (or delta, weight, strength, prominence, or other metric) of a facial feature of 2D image data **1352** from an average or template value represented by the corresponding principal component of principal components **1324**A-N. For example, difference metric **1374**A may represent a deviation of the subject's inner eye distance from the average distance within the images associated with 2D image dataset **1302**. As previously described, difference metrics **1374**A-N may correspond to a multiplier, difference, or other operation with respect to the template facial features represented by principal components **1324**A-N.

In some embodiments, template morphological model **1382** may correspond to a generic 3D model of an object, such as a human face (e.g., 3D model **1114** of FIG. **11**). The 3D landmark data of the generic 3D model can each correspond to a principal component of principal components **1324**A-N and an average or template value associated with the corresponding principal component. In some embodiments, template morphological model **1382** may be generated or configured (e.g., manually, or automatically) based on principal components **1324**A-N such that each landmark represents the average facial feature of the corresponding principal component. In some embodiments, each landmark may correspond to one or more vertices, lines, faces, or other geometry of the model associated with the landmark's facial feature, and landmarks may share geometry. Template morphological model **1382** may further be configured such that a landmark may be modified (e.g., morphed) based on a difference metric of PCA data **1372**. For example, a landmark may be associated with a control variable that modifies the landmark to increase or decrease the prominence (or other metric) of the corresponding facial feature. The geometry associated with the landmark will be modified as a result. In an example, a vertex of template morphological model **1382** located at the inner corner of the eye may be associated with both an inner eye distance landmark (corresponding to an inner eye distance facial feature) and an eye angle landmark (corresponding to an eye angle facial feature). Morphing the control variables of either landmark may change the coordinates of the vertex.

In some embodiments, PCA data **1372** and template morphological model **1382** may be provided as input to morphological model generation engine **1380** for generation of 3D model **1390**. 3D model **1390** can be similar to 3D model **1114** of FIG. **11**, unless otherwise described. Morphological model generation engine **1380** may use difference metrics **1374**A-N of PCA data **1372** to modify the corresponding landmarks of template morphological model **1382** to generate in 3D model **1390** that is representative of the subject's face. For example, a control variables of template morphological model **1382** may be multiplied by or added to respective ones of difference metrics **1374**A-N to accurately represent the subject's unique facial features in 3D model **1390**.

FIG. **14**A illustrates a flow diagram of an example of a method **1400** for training a PCA model, in accordance with embodiments of the disclosure. FIG. **14**B illustrates a flow diagram of an example of a method **1420** for using a trained PCA model, in accordance with embodiments of the disclosure. Methods **1400** and **1420** may be performed by processing logic that may comprise hardware (e.g., circuitry, dedicated logic, etc.), computer-readable instructions such as software or firmware (e.g., run on a general-purpose computing system or a dedicated machine), or a combination thereof. Methods **1400** and **1420** may also be associated with sets of instructions stored on a non-transitory computer-readable medium (e.g., magnetic, or optical disk, etc.). The instructions, when executed by a processing device, may cause the processing device to perform operations comprising the blocks of methods **1400** and **1420**. In an embodiment, methods **1400** and **1420** are performed by system **100** of FIG. **1**. In an embodiment, blocks of a particular method depicted in FIGS. **14**A-B can be performed simultaneously or in different orders than depicted. Various embodiments may include additional blocks not depicted in FIGS. **14**A-B or a subset of blocks depicted in FIGS. **14**A-B.

Referring to FIG. **14**A, at block **1402**, processing logic identifies 2D image data, which may correspond to images of human faces. For example, processing logic may identify the 2D image data **1303** corresponding to one or more images **1302**. The 2D images of human faces may be images of a training set, which may be manually or automatically curated.

At block **1404**, the processing logic preprocesses the 2D image data. For example, preprocessing engine **1306** may select 2D image data to elicit human-derived principal components corresponding to human-derived facial features as described above with reference to FIG. **13**. Other preprocessing may occur at block **1404**, such as normalizing the 2D image data, cropping the 2D image data to consistent dimensions, augmenting the 2D image data to generate additional training data, etc.

At block **1406**, the processing logic trains a PCA model with principal component analysis techniques using the 2D image data from the previous blocks. In some embodiments, the resulting principal components of the trained PCA model may correspond to human-derived facial features or computer-derived facial features or a combination thereof. In an embodiment, blocks **1404**-**1406** may be repeated in a loop to achieve desired principal components (e.g., corresponding to human-derived facial features) as described above with reference to FIGS. **12**A-B.

At block **1408**, processing logic refines the principal components of the PCA model. For example, postprocessing engine **1310** may prune or modify non-human-derived principal components or may combine human-derived components from different training blocks (e.g., each block **1406** associated with a different training set of 2D image data).

Referring to FIG. **14**B, at block **1422**, processing logic preprocesses input 2D image data (e.g., corresponding to an image of a subject's face). For example, preprocessing engine **1306** may normalize the input 2D image data, flatten it to a vector, or perform other preprocessing operations.

At block **1424**, processing logic provides the preprocessed 2D image data as input to the trained PCA model.

At block **1426**, processing logic obtains an output of the PCA model corresponding to weights of the principal components. For example, in blocks **1424** and **1426**, the preprocessed input 2D image data may be projected onto the eigenspace defined by the principal components, and the weights indicating the deviation of the input 2D image data from the training set (e.g., difference metrics) may be obtained from the projection.

At block **1428**, the processing logic modifies landmarks of a 3D model (e.g., a morphological model of a template face) based on the output of the PCA model. For example, landmarks **1202**A-N of 3D model **1200** may be modified based on a deviation (e.g., difference metrics) from the template model indicated by the weights obtained at block **1426**.

FIG. **15** is a block diagram illustrating an exemplary computer system, system **1500**, in accordance with embodiments of the disclosure. The system **1500** executes one or more sets of instructions that cause the machine to perform any one or more of the methodologies discussed herein. Set of instructions, instructions, and the like can refer to instructions that, when executed system **1500**, cause the system **1500** to perform one or more operations of training set generator **131** or beauty products module **151**. The machine can operate in the capacity of a server or a client device in client-server network environment, or as a peer machine in a peer-to-peer (or distributed) network environment. The machine can be a personal computer (PC), a tablet PC, a set-top box (STB), a personal digital assistant (PDA), a mobile telephone, a web appliance, a server, a network router, switch or bridge, or any machine capable of executing a set of instructions (sequential or otherwise) that specify actions to be taken by that machine. Further, while only a single machine is illustrated, the term "machine" shall also be taken to include any collection of machines that individually or jointly execute the sets of instructions to perform any one or more of the methodologies discussed herein.

The system **1500** includes a processing device **1502**, a main memory **1504** (e.g., read-only memory (ROM), flash memory, dynamic random-access memory (DRAM) such as synchronous DRAM (SDRAM) or Rambus DRAM (RDRAM), etc.), a static memory **1506** (e.g., flash memory, static random-access memory (SRAM), etc.), and a data storage device **1516**, which communicate with each other via a bus **1508**.

The processing device **1502** represents one or more general-purpose processing devices such as a microprocessor, central processing unit, or the like. More particularly, the processing device **1502** can be a complex instruction set computing (CISC) microprocessor, reduced instruction set computing (RISC) microprocessor, very long instruction word (VLIW) microprocessor, or a processing device implementing other instruction sets or processing devices implementing a combination of instruction sets. The processing device **1502** can also be one or more special-purpose processing devices such as an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), a digital signal processor (DSP), network processor, or the like. The processing device **1502** is configured to execute instructions of the system **100**A or system **100**B and the training set generator **131** or beauty products module **151** for performing the operations discussed herein.

The system **1500** can further include a network interface device **1522** that provides communication with other machines over a network **1518**, such as a local area network (LAN), an intranet, an extranet, or the Internet. The system **1500** also can include a display device **1510** (e.g., a liquid crystal display (LCD) or a cathode ray tube (CRT)), an alphanumeric input device **1512** (e.g., a keyboard), a cursor control device **1514** (e.g., a mouse), and a signal generation device **1520** (e.g., a speaker).

The data storage device **1516** can include a computer-readable storage medium **1524** on which is stored the sets of instructions of the system **100**A or system **100**B and of training set generator **131** or of beauty products module **151** embodying any one or more of the methodologies or functions described herein. The computer-readable storage medium **1524** can be a non-transitory computer-readable storage medium. The sets of instructions of the system **100** and of training set generator **131** or of beauty products module **151** can also reside, completely or at least partially, within the main memory **1504** and/or within the processing device **1502** during execution thereof by the system **1500**, the main memory **1504** and the processing device **1502** also constituting computer-readable storage media. The sets of instructions can further be transmitted or received over the network **1518** via the network interface device **1522**.

While the example of the computer-readable storage medium **1524** is shown as a single medium, the term "computer-readable storage medium" can include a single medium or multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) that store the sets of instructions. The term "computer-readable storage medium" can include any medium that is capable of storing, encoding, or carrying a set of instructions for execution by the machine and that cause the machine to perform any one or more of the methodologies of the disclosure. The term "computer-readable storage medium" can include, but not be limited to, solid-state memories, optical media, and magnetic media.

In the foregoing description, numerous details are set forth. It will be apparent, however, to one of ordinary skill in the art having the benefit of this disclosure, that the disclosure can be practiced without these specific details. In some instances, well-known structures and devices are shown in block diagram form, rather than in detail, in order to avoid obscuring the disclosure.

Some portions of the detailed description have been presented in terms of algorithms and symbolic representations of operations on data bits within a computer memory. These algorithmic descriptions and representations are the means used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the art. An algorithm is here, and generally, conceived to be a self-consistent sequence of operations leading to a desired result. The operations are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like.

It can be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise, it is appreciated that throughout the description, discussions utilizing terms such as "generating," "providing," "obtaining," "identifying," "determining," or the like, refer to the actions and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (e.g., electronic) quantities within the computer system memories or registers into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

The disclosure also relates to an apparatus for performing the operations herein. This apparatus can be specially constructed for the required purposes, or it can include a general-purpose computer selectively activated or reconfigured by a computer program stored in the computer. Such a computer program can be stored in a computer readable storage medium, such as, but not limited to, any type of disk including a floppy disk, an optical disk, a compact disc read-only memory (CD-ROM), a magnetic-optical disk, a read-only memory (ROM), a random access memory (RAM), an erasable programmable read-only memory (EPROM), an electrically erasable programmable read-only memory (EEPROM), a magnetic or optical card, or any type of media suitable for storing electronic instructions.

The words "example" or "exemplary" are used herein to mean serving as an example, instance, or illustration. Any aspect or design described herein as "example" or "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects or designs. Rather, use of the words "example" or "exemplary" is intended to present concepts in a concrete fashion. As used in this application, the term "or" is intended to mean an inclusive "or" rather than an exclusive "or." That is, unless specified otherwise, or clear from context, "X includes A or B" is intended to mean any of the natural inclusive permutations. That is, if X includes A; X includes B; or X includes both A and B, then "X includes A or B" is satisfied under any of the foregoing instances. In addition, the articles "a" and "an" as used in this application and the appended claims can generally be construed to mean "one or more" unless specified otherwise or clear from context to be directed to a singular form. Moreover, use of the term "an implementation" or "one implementation" or "an embodiment" or "one embodiment" throughout is not intended to mean the same implementation or embodiment unless described as such. The terms "first," "second," "third," "fourth," etc. as used herein are meant as labels to distinguish among different elements and cannot necessarily have an ordinal meaning according to their numerical designation.

For simplicity of explanation, methods herein are depicted and described as a series of acts or operations. However, acts in accordance with this disclosure can occur in various orders and/or concurrently, and with other acts not presented and described herein. Furthermore, not all illustrated acts can be required to implement the methods in accordance with the disclosed subject matter. In addition, those skilled in the art will understand and appreciate that the methods could alternatively be represented as a series of interrelated states via a state diagram or events. Additionally, it should be appreciated that the methods disclosed in this specification are capable of being stored on an article of manufacture to facilitate transporting and transferring such methods to computing devices. The term article of manufacture, as used herein, is intended to encompass a computer program accessible from any computer-readable device or storage media.

In additional embodiments, one or more processing devices for performing the operations of the above described embodiments are disclosed. Additionally, in embodiments of the disclosure, a non-transitory computer-readable storage medium stores instructions for performing the operations of the described embodiments. Also in other embodiments, systems for performing the operations of the described embodiments are also disclosed.

It is to be understood that the above description is intended to be illustrative, and not restrictive. Other embodiments will be apparent to those of skill in the art upon reading and understanding the above description. The scope of the disclosure can, therefore, be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled.

What is claimed is:

1. A method comprising:

receiving two-dimensional (2D) image data corresponding to a 2D image of an eye area of a subject;

generating, using the 2D image data and a template three-dimensional model, a three-dimensional (3D) model of the eye area;

determining, by a processing device, a relationship between a first landmark of the 3D model representing a first facial feature of the eye area and a second landmark of the 3D model representing a second facial feature of the eye area; and

identifying, among a plurality of false eyelashes, a subset of the plurality of false eyelashes using a search filter, wherein the search filter is based on the relationship between the first landmark and the second landmark of the 3D model.

2. The method of claim **1**, wherein identifying, among the plurality of false eyelashes, the subset of the plurality of false eyelashes based on the relationship between the first landmark and the second landmark further comprises:

determining a range of values corresponding to a characteristic associated with the plurality of false eyelashes based on the determined relationship; and

identifying, among the plurality of false eyelashes, the subset of the plurality of false eyelashes based at least in part on the range of values corresponding to the characteristic.

3. The method of claim **1**, wherein the relationship between the first landmark of the 3D model and the second landmark of the 3D model comprises a geometrical relationship between the first landmark and the second landmark.

4. The method of claim **3**, wherein determining the relationship between the first landmark of the 3D model representing the first facial feature of the eye area and the second landmark of the 3D model representing the second facial feature of the eye area, further comprises:

identifying the first landmark and the second landmark on the 3D model.

5. The method of claim **4**, wherein determining the relationship between the first landmark of the 3D model representing the first facial feature of the eye area and the second landmark of the 3D model representing the second facial feature of the eye area, further comprises:

determining a distance between the first landmark and the second landmark, the distance representing at least part of the relationship between the first landmark and the second landmark.

6. The method of claim **1**, wherein the first facial feature comprises an eyebrow of the subject and the second facial feature comprises an eye of the subject.

7. The method of claim **1**, further comprising:

providing, for presentation at a client device, an indication of the subset of false eyelashes;

receiving an indication of a user selection of a first false eyelash from the subset of false eyelashes; and

generating, for presentation at the client device, an updated 2D image of the eye area of the subject, the updated 2D image representing the first false eyelash applied to the eye area of the subject.

8. The method of claim **7**, wherein the subset of false eyelashes comprise artificial lash extensions designed for application at an underside of natural eyelashes, and wherein the updated 2D image represents one or more of the artificial lash extensions applied to the underside of natural lashes of the subject.

9. The method of claim **1**, further comprising:

determining, among a plurality of eye types, a first eye type corresponding to an eye of the subject, wherein identifying, among the plurality of false eyelashes, the subset of the plurality of false eyelashes is based at least in part on the first eye type corresponding to the eye of the subject.

10. The method of claim 9, further comprising:

receiving, among a plurality of lash styles, a user selection identifying a first lash style, wherein identifying, among the plurality of false eyelashes, the subset of the plurality of false eyelashes is based at least in part on the user selection identifying the first lash style.

11. The method of claim 1, wherein generating, using the 2D image data, the 3D model of the eye area comprises:

providing the 2D image data as input to a conversion system; and

obtaining one or more outputs of the conversion system, the one or more outputs corresponding to the 3D model.

12. A system comprising: a memory device; and

a processing device coupled to the memory device, the processing device to perform operations comprising:

receiving two-dimensional (2D) image data corresponding to a 2D image of an eye area of a subject;

generating, using the 2D image data and a template three-dimensional model, a three-dimensional (3D) model of the eye area;

determining a relationship between a first landmark of the 3D model representing a first facial feature of the eye area and a second landmark of the 3D model representing a second facial feature of the eye area; and

identifying, among a plurality of false eyelashes, a subset of the plurality of false eyelashes using a search filter, wherein the search filter is based on the relationship between the first landmark and the second landmark of the 3D model.

13. The system of claim 12, wherein identifying, among the plurality of false eyelashes, the subset of the plurality of false eyelashes based on the relationship between the first landmark and the second landmark further comprises:

determining a range of values corresponding to a characteristic associated with the plurality of false eyelashes based on the determined relationship; and

identifying, among the plurality of false eyelashes, the subset of the plurality of false eyelashes based at least in part on the range of values corresponding to the characteristic.

14. The system of claim 12, wherein the relationship between the first landmark of the 3D model and the second landmark of the 3D model comprises a geometrical relationship between the first landmark and the second landmark.

15. The system of claim 14, wherein determining the relationship between the first landmark of the 3D model representing the first facial feature of the eye area and the second landmark of the 3D model representing the second facial feature of the eye area, further comprises:

identifying the first landmark and the second landmark on the 3D model.

16. The system of claim 15, wherein determining the relationship between the first landmark of the 3D model representing the first facial feature of the eye area and the second landmark of the 3D model representing the second facial feature of the eye area, further comprises:

determining a distance between the first landmark and the second landmark, the distance representing at least part of the relationship between the first landmark and the second landmark.

17. A non-transitory computer-readable medium comprising instructions that, when executed by a processing device, cause the processing device to perform operations comprising:

receiving two-dimensional (2D) image data corresponding to a 2D image of an eye area of a subject;

generating, using the 2D image data and a template three-dimensional model, a three-dimensional (3D) model of the eye

area;

determining a relationship between a first landmark of the 3D model representing

a first facial feature of the eye area and a second landmark of the 3D model representing a second facial feature of the eye area; and

identifying, among a plurality of false eyelashes, a subset of the plurality of false eyelashes using a search filter, wherein the search filter is based on the relationship between the first landmark and the second landmark of the 3D model.

18. The non-transitory computer-readable medium of claim 17, wherein the first facial feature comprises an eyebrow of the subject and the second facial feature comprises an eye of the subject.

19. The non-transitory computer-readable medium of claim 17, the operations further comprising:

providing, for presentation at a client device, an indication of the subset of false eyelashes;

receiving an indication of a user selection of a first false eyelash from the subset of false eyelashes; and

generating, for presentation at the client device, an updated 2D image of the eye area of the subject, the updated 2D image representing the first false eyelash applied to the eye area of the subject.

20. The non-transitory computer-readable medium of claim 19, wherein the subset of false eyelashes comprise artificial lash extensions designed for application at an underside of natural eyelashes, and wherein the updated 2D image represents one or more of the artificial lash extensions applied to the underside of natural lashes of the subject.

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