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(54) **AUTOMATED SYSTEM FOR GENERATION OF FACIAL ANIMATION RIGS**

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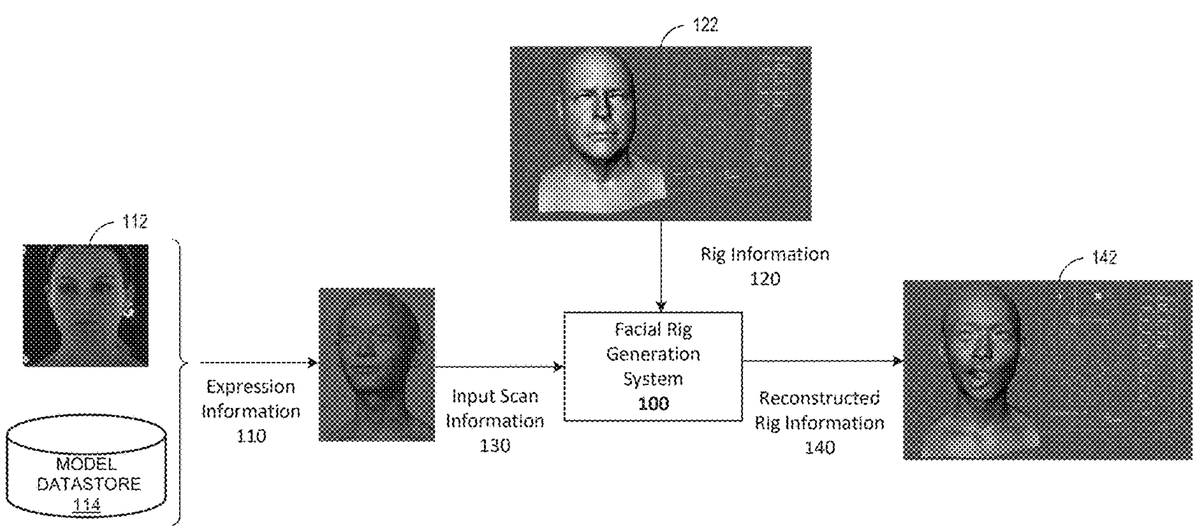
(57) **ABSTRACT**

Systems and methods are provided for technical improvements with respect to generation of facial expressions, facial riggings, and models for characters configured for use in electronic games. The systems and methods may generate a facial animation rig that can be used to generate realistic facial expressions based on analyzing data captured from real-world persons. Advantageously, the system may allow for substantially automated facial rig generation.

20 Claims, 8 Drawing Sheets



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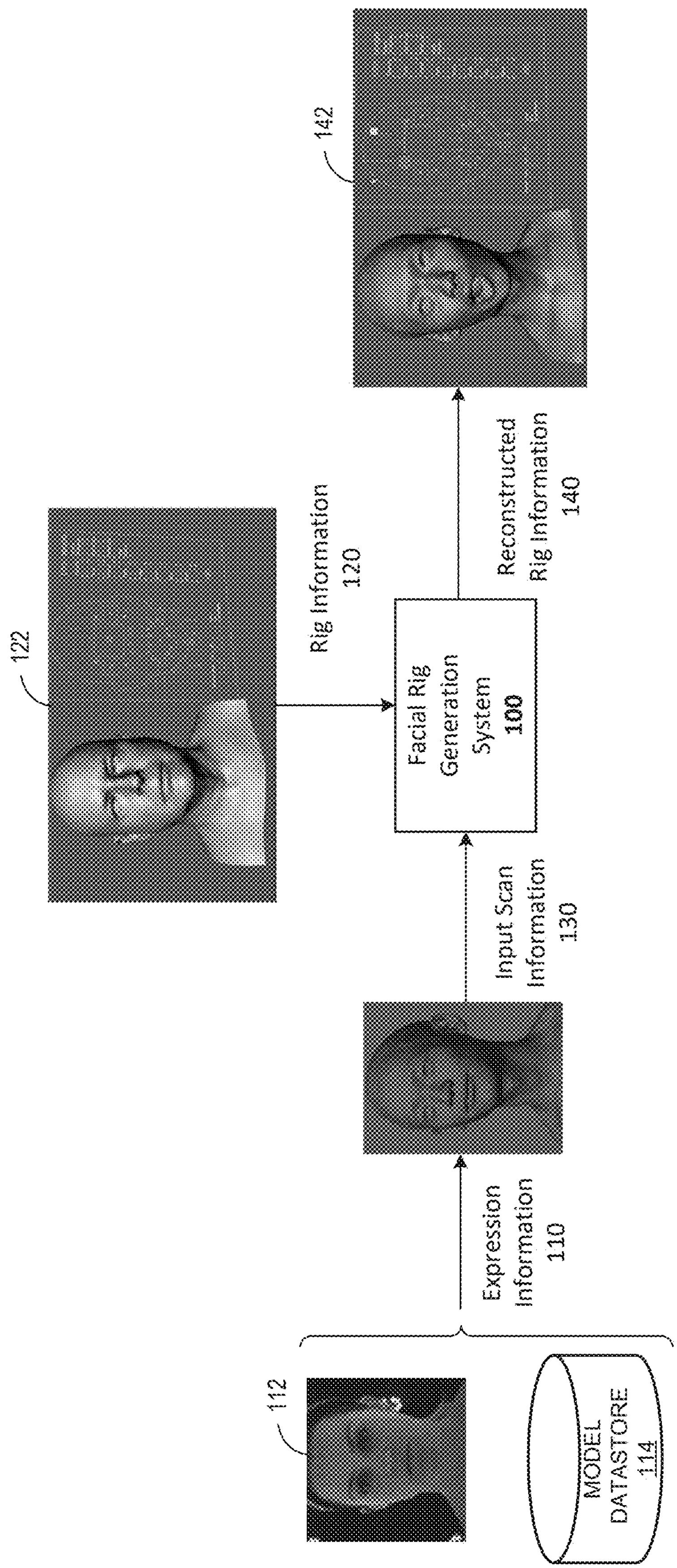
112
MODEL DATASTORE 114
Expression Information 110
Input Scan Information 130
122
Rig Information 120
Facial Rig Generation System 100
Reconstructed Rig Information 140
142

FIG. 1

200

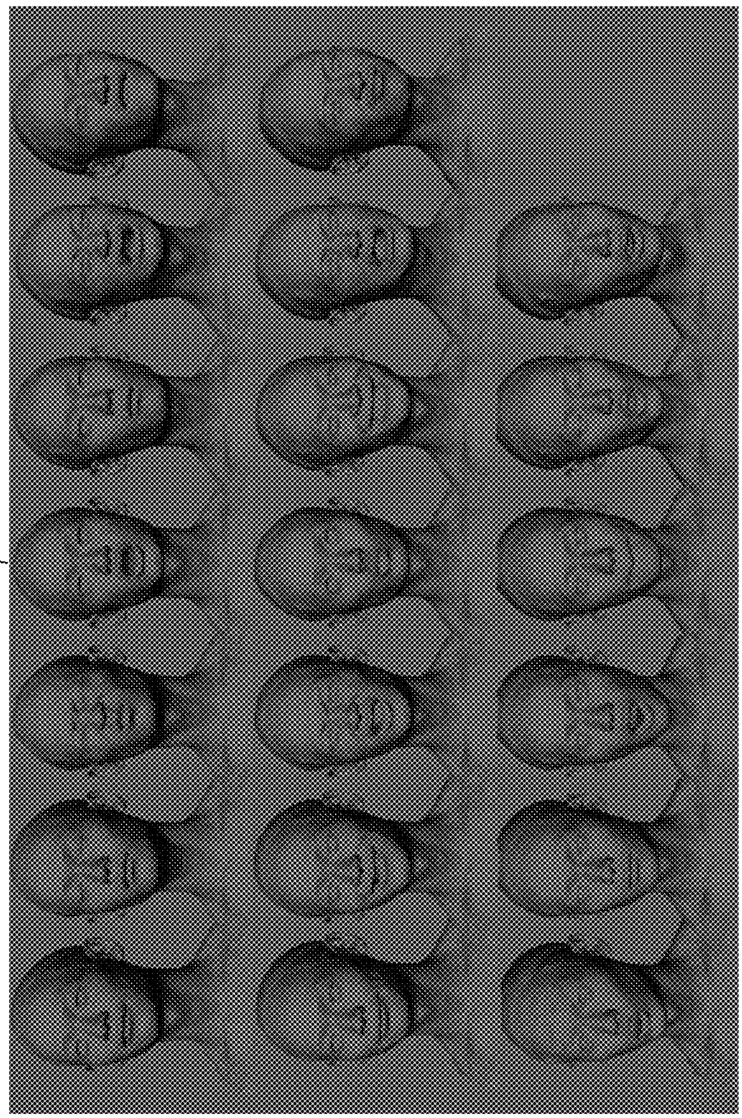

FIG. 2

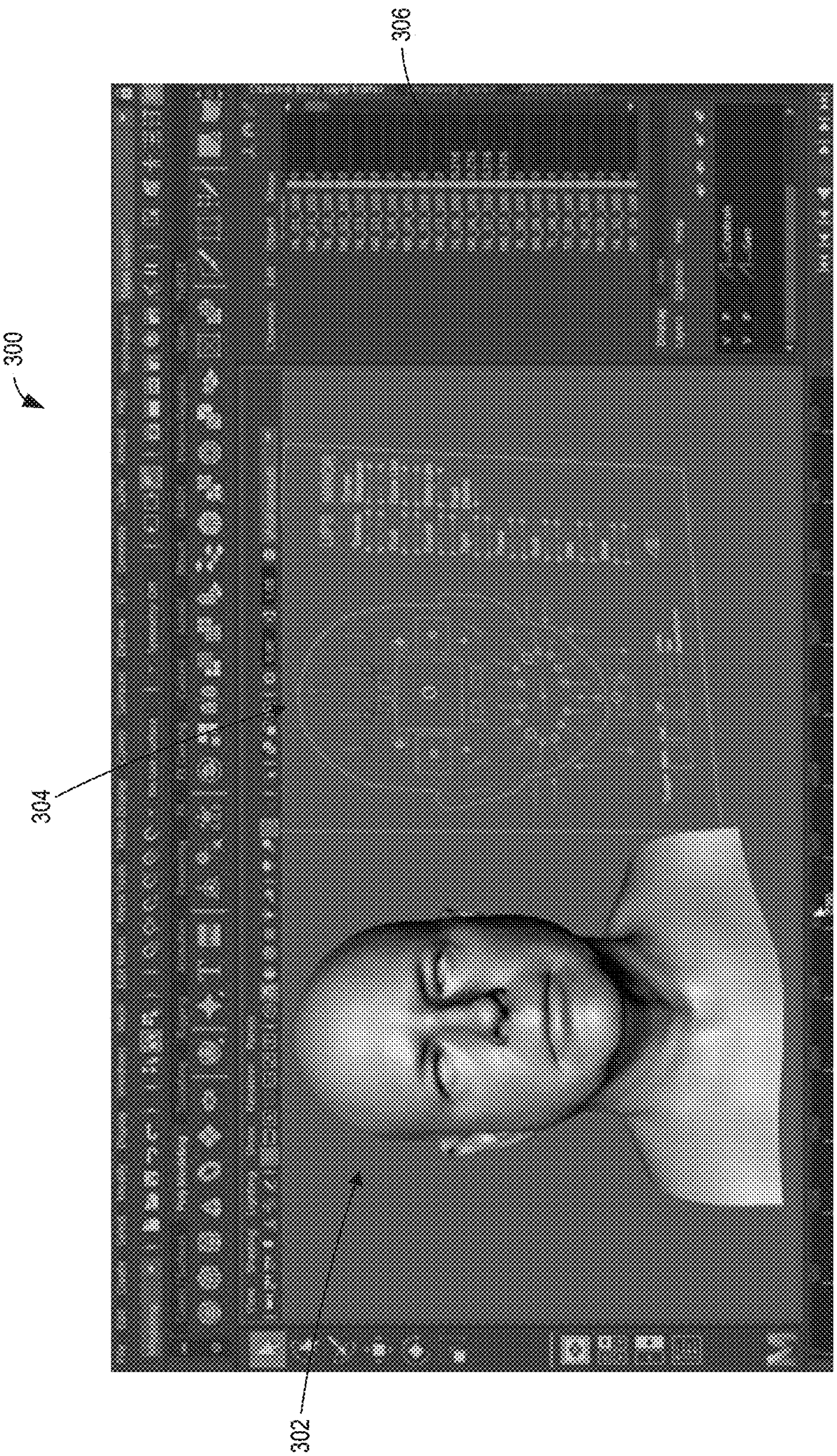

FIG. 3

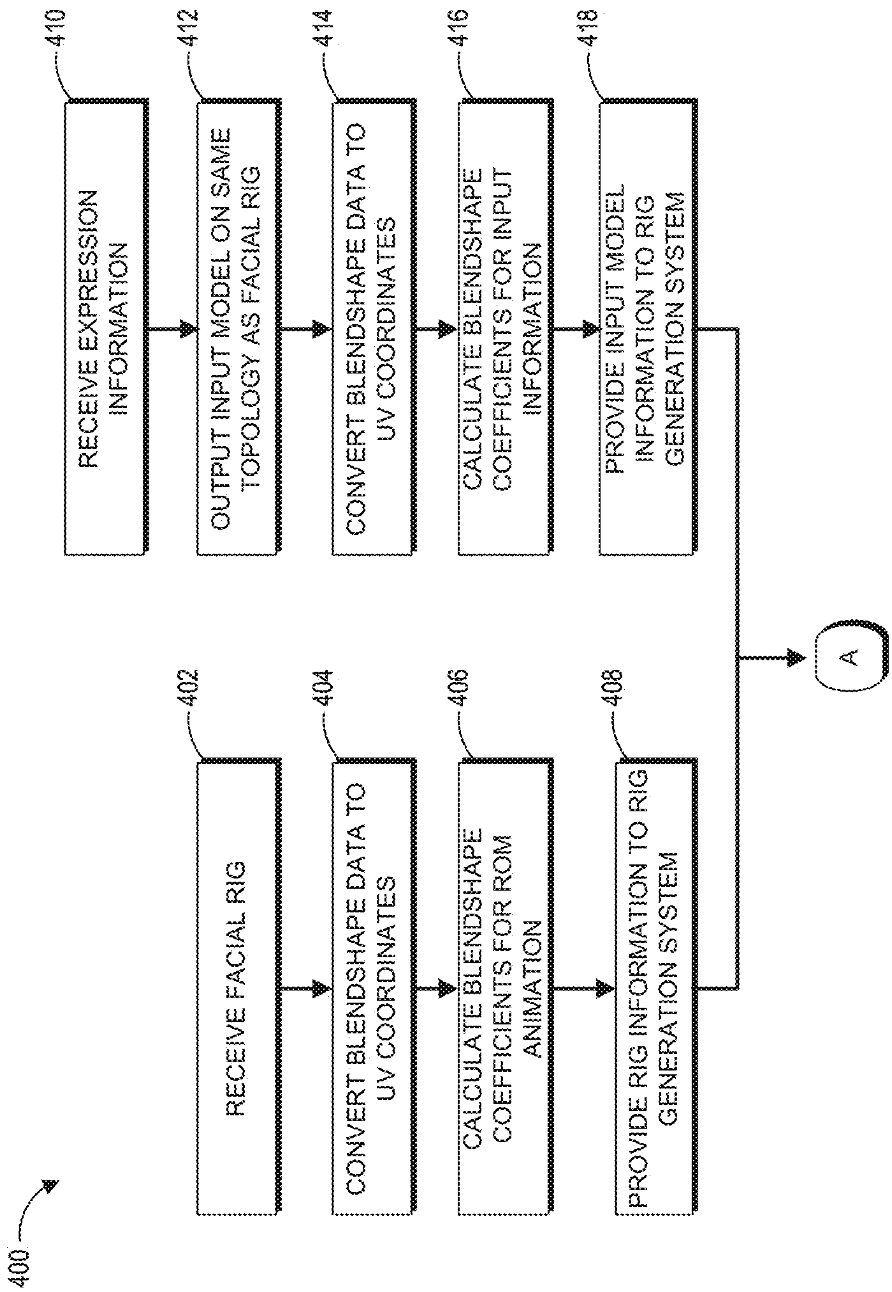
400
402
RECEIVE FACIAL RIG
404
CONVERT BLENDSHAPE DATA TO UV COORDINATES
406
CALCULATE BLENDSHAPE COEFFICIENTS FOR ROM ANIMATION
408
PROVIDE RIG INFORMATION TO RIG GENERATION SYSTEM
410
RECEIVE EXPRESSION INFORMATION
412
OUTPUT INPUT MODEL ON SAME TOPOLOGY AS FACIAL RIG
414
CONVERT BLENDSHAPE DATA TO UV COORDINATES
416
CALCULATE BLENDSHAPE COEFFICIENTS FOR INPUT INFORMATION
418
PROVIDE INPUT MODEL INFORMATION TO RIG GENERATION SYSTEM
A

FIG. 4

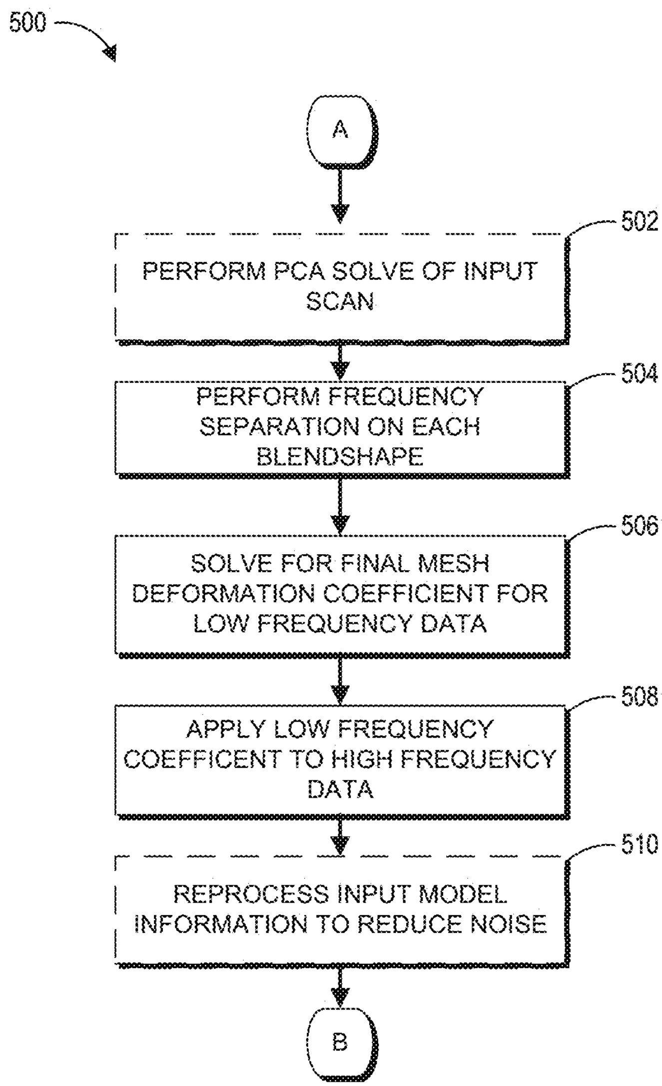
500
A
PERFORM PCA SOLVE OF INPUT SCAN
502
PERFORM FREQUENCY SEPARATION ON EACH BLENDSHAPE
504
SOLVE FOR FINAL MESH DEFORMATION COEFFICIENT FOR LOW FREQUENCY DATA
506
APPLY LOW FREQUENCY COEFFICENT TO HIGH FREQUENCY DATA
508
REPROCESS INPUT MODEL INFORMATION TO REDUCE NOISE
510
B

FIG. 5

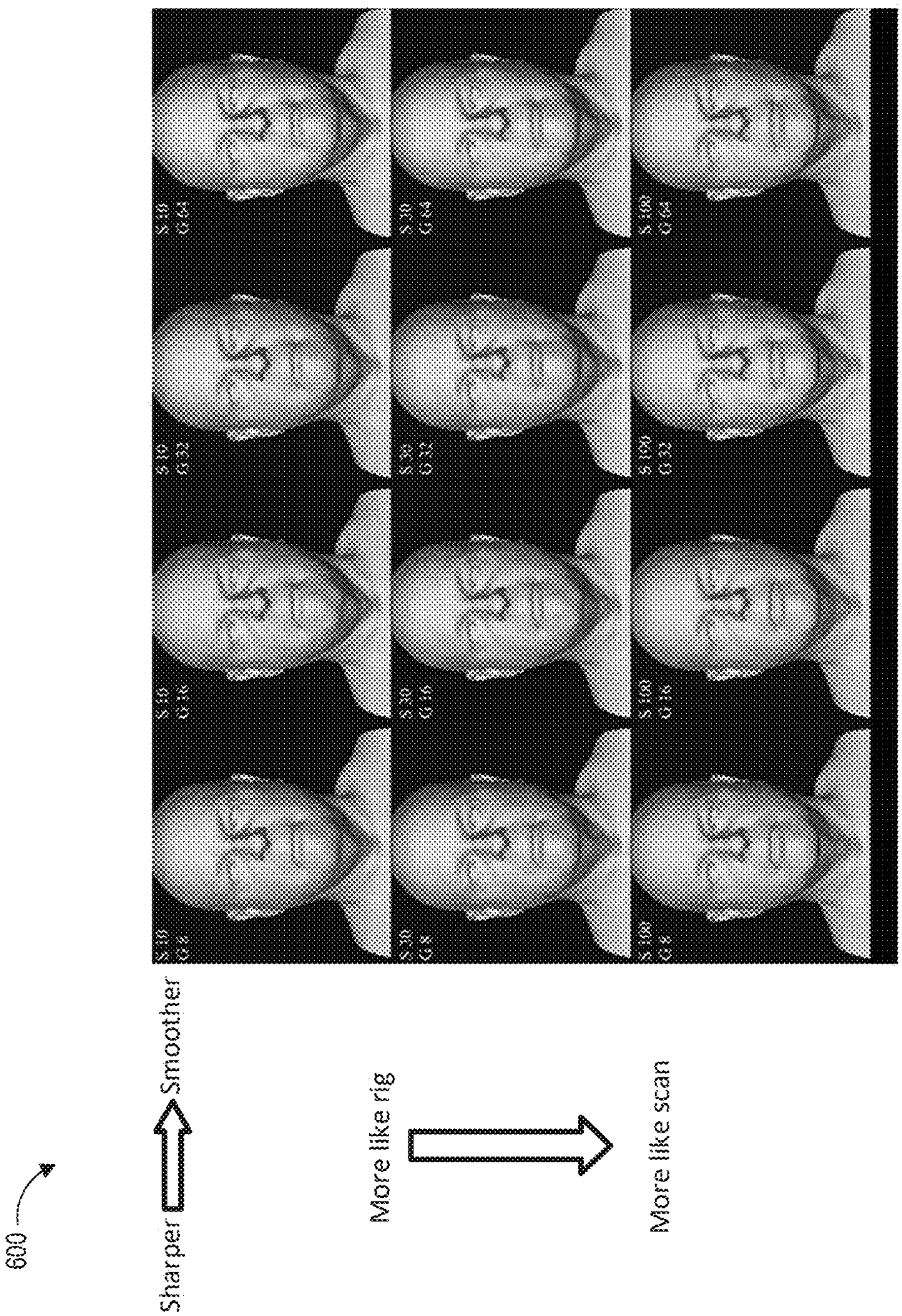
600
Sharper
Smoother
More like rig
More like scan
S 10
G 64
S 10
G 32
S 10
G 16
S 10
G 8
S 30
G 64
S 30
G 32
S 30
G 16
S 30
G 8
S 100
G 64
S 100
G 32
S 100
G 16
S 100
G 8

FIG. 6

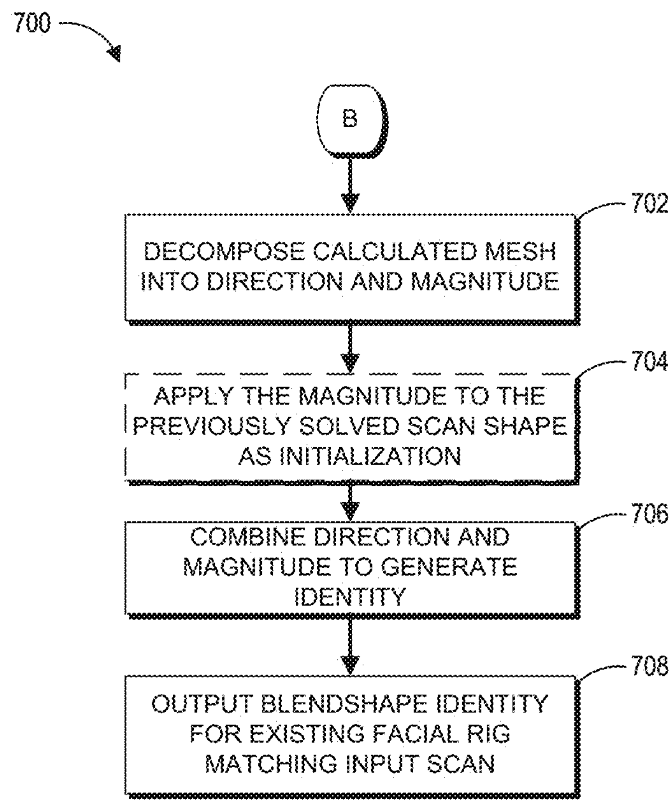
700
B
DECOMPOSE CALCULATED MESH INTO DIRECTION AND MAGNITUDE
702
APPLY THE MAGNITUDE TO THE PREVIOUSLY SOLVED SCAN SHAPE AS INITIALIZATION
704
COMBINE DIRECTION AND MAGNITUDE TO GENERATE IDENTITY
706
OUTPUT BLENDSHAPE IDENTITY FOR EXISTING FACIAL RIG MATCHING INPUT SCAN
708

FIG. 7

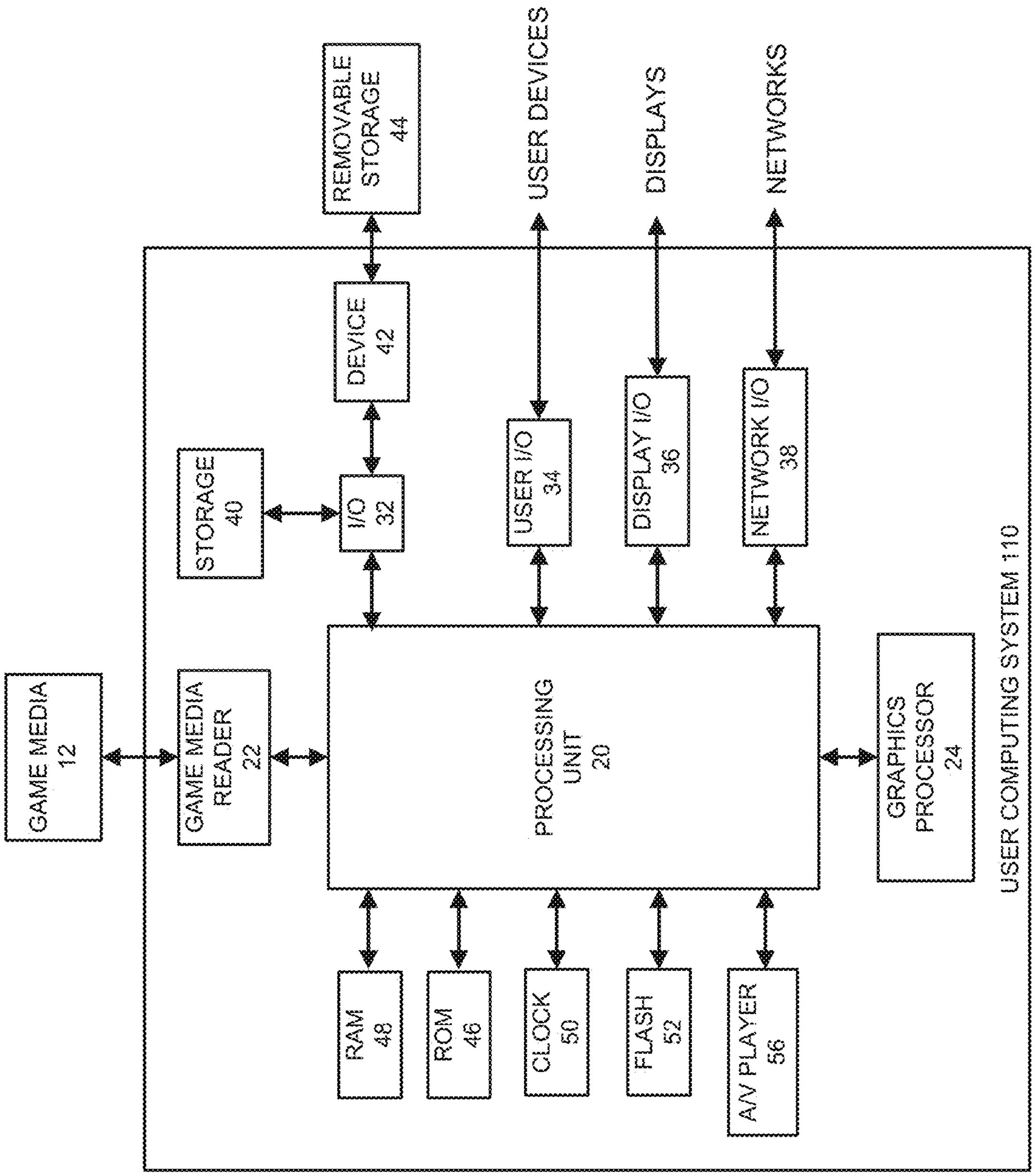
GAME MEDIA
12
GAME MEDIA
READER
22
STORAGE
40
I/O
32
DEVICE
42
REMOVABLE
STORAGE
44
USER DEVICES
DISPLAYS
NETWORKS
USER I/O
34
DISPLAY I/O
36
NETWORK I/O
38
PROCESSING
UNIT
20
GRAPHICS
PROCESSOR
24
RAM
48
ROM
46
CLOCK
50
FLASH
52
A/V PLAYER
56
USER COMPUTING SYSTEM 110

FIG. 8

AUTOMATED SYSTEM FOR GENERATION OF FACIAL ANIMATION RIGS

TECHNICAL FIELD

The present disclosure relates to systems and techniques for generation of facial animation rig for virtual character models.

BACKGROUND

Electronic games are increasingly becoming more realistic due to an increase in available processing resources. The games can include rich, lifelike, characters that are created to follow complex scripts, and are placed in video games via computationally expensive animation processes. This increase in realism may allow for more realistic gameplay experiences. For example, elements that form an in-game world, such as characters, may be more realistically presented. In this example, the elements may be increasingly rendered at higher resolutions, with more detailed textures, with more detailed underlying meshes, and so on. While this added realism may be beneficial to an end-user of an electronic game, it may place a substantial burden on electronic game designers. As an example, electronic game designers may be required to create very rich, and detailed, models of character faces and expressions. As another example, electronic game designers may be required to create fluid, lifelike, expressions for each character within a game.

A character may be animated to emote, and in so doing the character's face may express disparate feelings while providing dialogue. For example, a character may express feelings of happiness, apprehension, fear, and so on. Generally, video game modelers are required to manipulate a 3D model of a character's face to arrive at each emotion. As an example, a video game modeler may modify the character's face to appear happy. This modification may stem from the video game modeler's utilization of software to create a 3D model of the character's face, and then adjust the 3D model until it conforms to the emotion required. However, each character's range of facial expressions are required to be modeled separately. That is, a video game modeler will have to uniquely adjust a 3D model of each character's face until the face arrives at each of defined facial expression. The process can result in a large amount of work which is not transferable between characters.

Additionally, an animator can create a facial animation rig that can be used to adjust the character's face after it has been modeled. The process of facial rigging is a complex process that is not easily transferable and can take a significant amount of development time, sometimes months of developer time to create a facial animation rig. For example, a modeler can create a happy face for an elderly character, and one or more variations that express slightly different emotions that are related to being happy (e.g., a bemused look). When the character is being animated, a video game animator may only be able to select from the happy face, or pre-configured variations, when animating a scene. If the developer wants to create facial expressions for a child, they will need to create a different facial rig and go through the entire process again. As the elderly person's facial rigging would not appropriately convey the character's facial expressions. Thus the process can be quite cumbersome to create facial animation riggings for characters within a game.

SUMMARY OF CERTAIN EMBODIMENTS

Particular embodiments of the subject matter described in this specification can be implemented so as to realize one or more of the following advantages. Utilizing the techniques described herein, realistic facial animations may be rapidly generated for character models configured for use in electronic games. As will be described, techniques may be employed to learn representations of distinct human faces. For example, a facial model may be defined, at least in part, based on positions of a multitude of features on the human face. Example features may include eyes, a nose, a mouth, ears, and so on. As may be appreciated, these features may be adjusted on a person to generate various expressions or perform various actions, such as speak, blink, and the like.

At present, techniques to generate facial animations and models for character models may rely upon designers generating and adjusting the character models to define different types of expressions. For example, to define smiling, a designer would need to define the positions of the features of the face of the model. In this example, the designer may upturn the position the corners of mouth, and so on. While this may allow for a smile to be generated, it may also involve a substantial burden on the designer.

In the present disclosure, techniques can be used to generate facial animation rigging based on real world expression data generated by humans and existing facial rigging systems. The facial animation rigging can be generated based on existing character models and/or real-world facial expression data that can be captured using a capture device. In such an embodiment, the capture device can be a standard 2D capture device such as a camera, a phone, or other device that can be used to capture still images and/or video data. The expression data can be pre-processed and configured so that it is in a format that is usable by the facial rig generation system to generate new facial animation rigs.

The techniques described herein therefore improve upon the functioning of prior software-based techniques to generate movement of in-game character models. As described above, prior techniques relied upon by designers to adjust positions of facial features on a skeleton underlying a character model. In contrast, the techniques described herein may allow for automated generation and adjustment of facial rigging systems. Advantageously, the automated adjustment of the facial rigging system allows for complicated rigging for animations to be quickly generated. In the present disclosure, techniques can be used to generate facial animation tools that are specific to input received for a real-world person. The facial rigging system can generate a facial rigging with an identity that corresponds to the input data provided.

In some aspects, the techniques described herein relate to a computer-implemented method including: accessing a first facial rig having a rig topology, a range of motion data of facial characteristics of the first facial rig, and calculated positional coefficients for the range of motion data, wherein the first facial rig has a first rig identity; receiving input scan data including an input facial model and a plurality of facial expressions of facial characteristics of the input model, wherein the input facial model uses the topology of the first facial rig, wherein the input facial model has a facial model identity; calculating coefficients of the input facial model for each of the plurality of facial expressions; calculating frequency separation for a defined range of the motion data of the first facial rig resulting in first high frequency data and first low frequency data; calculating frequency separation on each of the plurality of facial expressions of the input model resulting in second high frequency data and second low frequency data; matching portions of the second low frequency data to corresponding portions of the first low frequency data; identifying second high frequency data corresponding to the matched first low frequency data; generating a mesh based on the second high frequency data; and outputting a second facial rig based on the mesh, wherein the second facial rig has a second rig identity that corresponds to the facial model identity of the input scan data.

In some aspects, the techniques described herein relate to a computer-implemented method, wherein the input facial model is a three dimensional model.

In some aspects, the techniques described herein relate to a computer-implemented method, wherein the three dimensional model is based on two dimensional input data of a person.

In some aspects, the techniques described herein relate to a computer-implemented method, wherein the input facial model is composed of a plurality of blendshapes.

In some aspects, the techniques described herein relate to a computer-implemented method further including dividing the blendshapes into regions and calculating coefficients for each region in each of the plurality of expressions.

In some aspects, the techniques described herein relate to a computer-implemented method, wherein the coefficients correspond to displacement of the input model relative to a neutral state for each region of the input model.

In some aspects, the techniques described herein relate to a computer-implemented method, wherein the plurality of facial expressions of facial characteristics of the input model are a sequence of animations.

In some aspects, the techniques described herein relate to a computer-implemented method further including decomposing input scan data into direction and magnitude.

In some aspects, the techniques described herein relate to a computer-implemented method further including combining the direction and magnitude to generate the second facial rig.

In some aspects, the techniques described herein relate to a computer-implemented method further including performing principle component analysis on input scan prior to calculating frequency separation.

In some aspects, the techniques described herein relate to a computer-implemented method further including calculating a final mesh deformation of the plurality of expressions using matrix multiplication based at least in part on the coefficients of the input facial model.

In some aspects, the techniques described herein relate to a computer-implemented method, wherein the frequency separation is calculated using a Laplacian filter.

In some aspects, the techniques described herein relate to a system including one or more processors and non-transitory computer storage media storing instructions that when executed by the one or more processors, cause the one or more processors to perform operations including: accessing a first facial rig having a rig topology, a range of motion data of facial characteristics of the first facial rig, and calculated positional coefficients for the range of motion data, wherein the first facial rig has a first rig identity; receiving input scan data including an input facial model and a plurality of facial expressions of facial characteristics of the input model, wherein the input facial model uses the topology of the first facial rig, wherein the input facial model has a facial model identity; calculating coefficients of the input facial model for each of the plurality of facial expressions; calculating frequency separation for a defined range of the motion data of the first facial rig resulting in first high frequency data and first low frequency data; calculating frequency separation on each of the plurality of facial expressions of the input model resulting in second high frequency data and second low frequency data; matching portions of the second low frequency data to corresponding portions of the first low frequency data; identifying second high frequency data corresponding to the matched first low frequency data; generating a mesh based on the second high frequency data; and outputting a second facial rig based on the mesh, wherein the second facial rig has a second rig identity that corresponds to the facial model identity of input scan data.

In some aspects, the techniques described herein relate to a system, wherein the input facial model is composed of a plurality of blendshapes.

In some aspects, the techniques described herein relate to a system further including dividing the blendshapes into regions and calculating coefficients for each region in each of the plurality of expressions.

In some aspects, the techniques described herein relate to a system, wherein the coefficients correspond to displacement of the input model relative to a neutral state for each region of the input model.

In some aspects, the techniques described herein relate to a system further including decomposing input scan data into direction and magnitude.

In some aspects, the techniques described herein relate to a system further including combining the direction and magnitude to generate the second facial rig.

In some aspects, the techniques described herein relate to a system further including calculating a final mesh deformation of the plurality of expressions using matrix multiplication based at least in part on the coefficients of the input facial model.

In some aspects, the techniques described herein relate to a non-transitory computer storage medium storing instructions that when executed by one or more processors, cause the one or more processors to perform operations including: accessing a first facial rig having a rig topology, a range of motion data of facial characteristics of the first facial rig, and calculated positional coefficients for the range of motion data, wherein the first facial rig has a first rig identity; receiving input scan data including an input facial model and a plurality of facial expressions of facial characteristics of the input model, wherein the input facial model uses the topology of the first facial rig, wherein the input facial model has a facial model identity; calculating coefficients of the input facial model for each of the plurality of facial expressions; calculating frequency separation for a defined range of the motion data of the first facial rig resulting in first high frequency data and first low frequency data; calculating frequency separation on each of the plurality of facial expressions of the input model resulting in second high frequency data and second low frequency data; matching portions of the second low frequency data to corresponding portions of the first low frequency data; identifying second high frequency data corresponding to the matched first low frequency data; generating a mesh based on the second high frequency data; and outputting a second facial rig based on the mesh, wherein the second facial rig has a second rig identity that corresponds to the facial model identity of input scan data.

The systems, methods, and devices of this disclosure each have several innovative aspects, no single one of which is solely responsible for all of the desirable attributes disclosed herein.

Although certain embodiments and examples are disclosed herein, inventive subject matter extends beyond the examples in the specifically disclosed embodiments to other alternative embodiments and/or uses, and to modifications and equivalents thereof.

The details, including optional details, of one or more embodiments of the subject matter of this specification are set forth in the accompanying drawings and the description below. Other optional features, aspects, and advantages of the subject matter will become apparent from the description, the drawings, and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Throughout the drawings, reference numbers are re-used to indicate correspondence between referenced elements. The drawings are provided to illustrate embodiments of the subject matter described herein and not to limit the scope thereof.

FIG. **1** illustrates a block diagram of an example rig generation system.

FIG. **2** illustrates examples of input scan information for a rig generation engine.

FIG. **3** illustrates an example rig system for a facial model.

FIG. **4** is a flowchart of an example process for preprocessing input model information for use with the rig generation engine.

FIG. **5** illustrates a flow chart of an example process for generating a rig using the rig generation system.

FIG. **6** illustrates another flow chart of an example process for generating a rig using the rig generation system.

FIG. **7** illustrates an example outputs of filters used by the rig generation system.

FIG. **8** illustrates an embodiment of computing device according to the present disclosure.

Like reference numbers and designations in the various drawings indicate like elements.

DETAILED DESCRIPTION

Overview

This specification describes, among other things, technical improvements with respect to generation of facial expressions, facial riggings, and models for characters configured for use in electronic games. As will be described a system described herein (e.g., the rig generation system) may generate a facial animation rig (also referred to as a facial rig or rig) that can be used to generate realistic facial expressions based on analyzing data captured from real-world persons. Advantageously, the system may allow for substantially automated facial rig generation. While electronic games are described, it may be appreciated that the techniques described herein may be applied generally to generation of facial rigs for use with generation of facial expressions and features of character models. For example, animated content (e.g., TV shows, movies) may employ the techniques described herein.

The present disclosure provides a system for automating the process of facial rigging for new virtual characters. A facial animation rig is used by animators to generate facial expressions for a virtual character. The facial rig can generate facial expressions that correspond to a specific person. The process of generating a facial rig can be referred to as facial rigging and can be a laborious process for developers which can take a significant amount of time. Facial rigging is the process of adding controls to a face for animating facial expressions. These controls are commonly bound to either deformers or blendshapes, both of which modify the face's shape, scale, or orientation. The process includes creating the animation controls for a facial model and the animator's interface to those controls. The controls can provide for changing the weighting of feature points on the face in order to control the facial expressions, manually or automatically. These controls can be used to animate the facial expressions in accordance with motion data.

Facial expressions for an in-game character may be defined, at least in part, based on distinct positions of the facial features of the in-game character. The distinct positions, for example, may be blended together to generate the expression. As an example, each expression may represent a discrete sample of an animation sequence to be performed by the in-game character. Thus, if motion is to depict talking, each expression may represent a snapshot of the facial features during speaking. Even though each model can be configured to execute the same general facial expressions (e.g., smile, frown, etc.), each person has a unique way of implementing their own expression. As an example, the system may obtain a multitude of expressions of real-life persons. For example, there may be thousands, hundreds of thousands, and so on, obtained expressions. These expressions may, in some embodiments, be obtained from video of the real-life persons. Certain expressions may represent discrete snapshots of a real-life person.

Facial expressions may be provided as an input to the system. For example, observable features of the expression may be provided as an input. Example observable features may include positions of a facial model based on a real-life person (e.g., three-dimensional coordinates). These positions are referred to herein as facial features and may represent portions of a face or facial model which can move or be manipulated (e.g., eyes, nose, mouth, and so on).

In some embodiments, the techniques described herein can be used during the development process of the electronic game. In some embodiments, the techniques described herein may be performed during in-game gameplay of an electronic game. For example, a user may wish that an in-game character within an electronic game may have one or more expressions provided by the user. In this example, the user may provide video footage of the expression for the in-game character to mimic. The electronic game may thus generate a facial rig that is capable of generating a realistic sequence of expressions that correspond to the user's input.

In some embodiments, the user may provide an image of a face to be used for an in-game character to be used within the electronic game. For example, the present system can generate texture map(s) and meshes for generating a facial model for use as an in-game character within the electronic game.

Facial Rigging Generation System Overview

FIG. **1** illustrates a block diagram of an example facial rig generation system **100**. In the illustrated embodiment, the facial rig generation system **100** is configured to receive rig information **120**, and input scan information **130**, and generate reconstructed rig identity information **140**. The input scan information can be generated based on expression information **110**. The facial rig generation system **100** may, in some embodiments, be a system of one or more computers, one or more virtual machines executing on a system of one or more computers, and so on. In some embodiments, the facial rig generation system **100** may be implemented as a module, or software (e.g., an application), which may execute on a user device (e.g., a laptop, tablet, console gaming system, and so on).

Expression Information

The expression information **110** may be provided from capture data **112** and/or a model datastore **114**. One expression **112** in illustrated as being included in the expression information **110**. While only one expression is illustrated, it may be appreciated that thousands, hundreds of thousands, millions, and so on, expressions may be provided as input to the facial rig generation system **100**. The expression information **110** may be obtained via analyzing images and/or video of real-life persons. For example, it can be based on discrete images and/or 2D videos of faces preforming a predefined range of motions and then converted to an acceptable format for use with the facial rig generation system **100**.

In this example, each frame of the video may depict one or more expressions. As another example, motion capture information may be obtained from a capture studio. In this example, a person may be placed in a light room where multiple cameras are configured to synchronize the capture of facial data from all angles.

Each image and/or frame of video may be analyzed to identify features to be input into the facial rig generation system **100**. For example, the features may include locations of facial features. Example facial features may include a nose, cheeks, eyes, eyebrows, the forehead, ears, mouth, teeth, and so on. Thus, a facial feature may represent a portion of real-life person which is capable of movement or otherwise controlled by the real-life person. The locations of the facial features may be defined, in some embodiments, as two- or three-dimensional coordinates. For example, a coordinate reference frame may be defined. Each image and/or frame of video may be analyzed to map facial features of a real-life person onto the coordinate reference frame. As an example, movement of the eyes or mouth in a video clip may be analyzed to determine relative movement of each of the facial features. This relative movement may be translated to the coordinate reference frame for use by the facial rig generation system **100**. In some embodiments, deep learning techniques (e.g., convolutional neural networks) may be utilized to extract locations of the facial features. For example, a deep learning model may be trained to identify specific facial features depicted in an image or video frame.

Similarly, motion capture information may be analyzed to identify features to be input into the facial rig generation system **100**. Motion capture information may, in some embodiments, allow for rapid importation of locations of facial features on a real-life person. For example, the motion capture information may indicate locations of the person's facial features at discrete times. Each discrete time may be defined as a particular expression of the person. Thus, the location of the facial features may be identified for each expression.

The expression **112** is graphically depicted as representing the capture data for a particular expression. Though only a single image is illustrated, the capture data can be representative of video data that illustrates a range of expressions generated by the depicted person. Additionally, the capture data illustrated in **112** can be preprocessed in order to isolate the face and expression of the person. The image or video can be manipulated so that the face of the person is positioned in substantially the same position within the frame. The expression data can be manipulated, such as by scaling, cropping, and converting the color format of the capture data.

The expression **112** is graphically depicted as representing a particular expression, though it is generally indicative of a video including a plurality of expressions. In some embodiments, location information for facial features may be provided as an input to the facial rig generation system **100**. For example, the location information may be combined into a data structure, such as a vector or matrix, and define dimensional locations of the facial features. In some embodiments, expression information **110** including a multitude of expressions (e.g., hundreds, thousands, and so on) may be provided to the facial rig generation system **100**.

Rig Information

The rig information **120** includes a production facial animation rig that has previously been generated. The production facial rig is an operational rig with controls for animating facial expressions of a face having a defined identity. These controls are commonly bound to either deformers or blendshapes having a defined topology. The animation controls for the facial model can provide for changing the weighting of feature points on the face in order to control the facial expressions, manually or automatically. These controls can be used to animate the facial expressions in accordance with motion data. The rig information **120** also includes range of motion (ROM) data, which includes a defined set of ROM animation applied to the facial rig. Advantageously, the ROM data can include animations that encompasses substantially all of the facial movements and emotes capable by the production facial rig.

The rig information **120** can include positional data for each of the facial characteristics for all of the ROM data. The positional data can be provided for each frame of the ROM data. Such that each frame and it's corresponding positional information can include calculated positional data. The calculated positional data can include calculated positional coefficients. This data can be in the form of calculated coefficients for each blendshape. In some instances, the blendshapes can be converted to UV coordinates and divided into regions (e.g., 16×16). The coefficients can be calculated for each region within each frame of the ROM data. The rig information **120** is used as the basis for generating the reconstructed rig information **140** using the input scan information **130**.

With additional reference to FIG. **3**, an example of a facial animation rig **300** is illustrated. The facial animation rig includes a three-dimensional facial model **302**. Controls **304** for manipulating the positional features of the facial model are illustrated. Each of the controls provides for control of specific facial characteristics of the facial model. The controls define the minimums and maximums, relationships, correctives, and rules for which the various controls can be manipulated to change the expression of the facial model. Section **306** illustrates calculated coefficients for the positions of regions of the face. In the illustrated embodiment, the calculated coefficients can be determined relative to a neutral state of the facial model. Displacement from the neutral state can be represented by a value that deviates from zero.

Input Scan Information

The expression information **110** can be processed so that it is in a format that is usable by facial rig generation system **100**. The expression information **110** can be in various forms that can go through various processing steps to convert it from two-dimensional data to a three-dimensional model. Advantageously, the expression information will have a sufficient number of expressions that can be used by the facial rig generation system **100** to generate the reconstructed rig information **140**. The expressions can be in the form of a static poses and/or a continuous sequence of inputs (e.g., animations). An example of a series of static poses **200** are illustrated in FIG. **2**.

The input scan information **130** that is provided to the facial rig generation system **100** based on the expression data **110** is in format that uses the same topology as the production rig **122**. The expression information is converted to a 3D model, aligned, and pre-stabilized for use with the production rig topology. The input scan information **130** can be generated manually or automatically. The expressions can be static scans representing discreet expressions that have been generated based on the expression information, such as capture data received during motion capture or from a user. The input scan information **130** can include positional data for the expression data. The positional data can be provided for each discreet expression and/or frame of animation data. Such that each frame/expression and it's corresponding positional information can include calculated positional data. This data can be in the form of calculated coefficients for each blendshape. In some instances, the blendshapes can be converted to UV coordinates and divided into regions (e.g., 16×16). The coefficients can be calculated for each region within each frame of the ROM data.

The conversion from the original source data of the expression information is performed prior to proving the input scan information to the facial rig generation system **100**. The input scan information includes a plurality of expressions, whether they are discrete or continuous. The order of the expression is not of important, but rather it is advantageous that the shapes of the expressions are well varied in order to determine an adequate analysis of the face associated with the input scan information. The input scan information can be provided as input to the facial rig generation system **100** after the preprocessing is complete.

Reconstructed Rig Information

The facial rig generation system **100** can use the input scan information to output a reconstructed rig information **140**, which can include a new facial rig **142** that corresponds to the input scan information. By using the production rig **122**, the system can utilize frequency matching between the rig information **120** and the input scan information **130** to generate a new identity for the rig that corresponds to the facial animation characteristics of the input scan data.

Facial animation characteristics are different for each individual and each facial rig has a specific identity. The identity of a rig allows the developer to generate facial actions that are specific to the identity associated with the rig. By using this process for facial rigging, particular differences between the production rig **122** and the user scan information **130** can be analyzed and a new or reconstructed facial rig can be generated. The generated rig can be used by animators when animating and developing characters for a game.

As discussed herein, the facial rigs have the same general functionality in that the controls are manipulated into facial expressions, and the blendshapes of the facial rig are manipulated into an expression or animation. Generally, each person emotes differently. For example, each person has a slightly different smile, the position of the mouth, eyes, and other facial characteristics are different even for the same type of expression. By automating the development of facial animation rigs, the process can be reduced from a period of months to hours. The facial rig generation system **100** provides developers with the tools to automate the generation of facial rigs having a specific identity for any character within a game.

Rig Generation Process

FIGS. **4**, **5**, and **7** illustrate example processes used to generate a reconstructed facial rig **140** based on the expression information **110**, rig information **120**, and input scan information **130**. FIG. **4** is directed to processing the expression information and generating input scan information that can be used by the facial rig generation system **100** to generate the new facial rig. FIGS. **5** and **7** provide example processes executed by the facial rig generation system **100** for generating the new facial rig based on the input scan information associated with an input identity.

Advantageously, once a facial rig is generated for an input identity, such as a person A, the facial rig can be used to generate new expressions based on inputs that substantially correspond to how person A would make the expressions based on the input data. Greater amounts of input data will increase the correlation between input scan expressions (e.g., person A expressions) and the resulting expressions of the facial rig. Additionally, the new facial rig can be used with different models and the same identity of expressions can be output. For example, a facial rig generated based on how an elderly man would emote, could be replaced with the model of young girl and the facial characteristics of the model can then be moved based on the identity of the elderly man when emoting. These expressions may advantageously represent realistic expressions of persons. For example, the elderly man facial rig can be used with other models of a similar archetype (e.g., elderly men).

Example Flowchart—Processing Input Data

FIG. **4** is a flowchart of an example process **400** for processing expression data for use with the facial rig generation system **100**. For convenience, the process **400** will be described as being performed by a system of one or more computers (e.g., the facial rig generation system **100**). Blocks **402-408** relate to the rig information **120** and blocks **410-418** relate to the expression information **110** and the input scan information **130**.

At block **402**, the system receives a facial rig for use as a basis for the facial rig generation system **100**. The facial rig can be referred to as a production facial rig. The production facial rig is an operational rig with controls for animating facial expressions of a face having a defined identity. The controls of the facial rig allow for the control of blendshapes of the facial model. The rig information **120** also includes a defined set of range of motion (ROM) animation applied to the facial rig. Advantageously, the ROM data can include animations that encompasses substantially all of the facial movements and emotes capable by the production facial rig.

At block **404**, the system can convert the blendshape data to a UV coordinate system. The UV coordinate system may be used for mapping textures to the model and can be beneficial for the animation process. The data on UV coordinate system can be divided into regions of a defined size (e.g., 16×16).

At block **406**, the system can calculate blendshape coefficients for each frame of the ROM animation. The rig information **120** can include positional data for each of the facial characteristics for all of the ROM data. The positional data can be provided for each frame of the ROM data. Such that each frame and it's corresponding positional information can include calculated positional data. This data can be in the form of calculated coefficients for each blendshape. The coefficients can be calculated for each region of the model. Example coefficients are illustrated in section **306** of the embodiment of the facial rig illustrated in FIG. **3**. the calculated coefficients can be determined relative to a neutral state of the facial model. Deviation from the neutral state can be represented by a value different than zero.

At block **408**, the production facial rig and ROM are loaded into the facial rig generation system **100** for future processing. The facial rig generation system **100** can be facial rig agnostic, such that any type of facial rig can be loaded into the facial rig generation system **100**. The output of the facial rig generation system **100** will depend on the type of production facial rig loaded into the facial rig generation system **100**. As the analysis will be computed based the production rig utilized by the facial rig generation system **100**. As will be further described with respect to blocks **410-418**, the facial rig is used as the topology basis for the new input data.

At block **410**, the system can receive expression information that is used as the basis for the input scan data. The expression information **110** may be obtained via analyzing images and/or video of real-life persons. The expression information **110** may be provided from capture data **112**, a model datastore **114**, and/or another source. The expression information **110** can be based on discrete images and/or videos (2D or 3D) of faces preforming a predefined range of motions. Advantageously, the expression information will have a sufficient number of expressions that can be used by the system to generate the reconstructed rig information **140**.

At block **412**, the system generates or otherwise outputs an input model on the same topology as the facial rig. The expression information **110** can be processed so that it is in a format that is usable by facial rig generation system **100**. The expression information **110** can be in various forms that can go through various processing steps to convert it from two-dimensional data to a three-dimensional model. The input scan information **130** that is provided to the facial rig generation system **100** based on the expression data **110** is in format that uses the same topology as the production rig **122**. The expression information is converted to a 3D model, aligned, and pre-stabilized for use with the production rig topology.

At block **414**, the system can optionally convert the blendshape data to a UV coordinate system. The UV coordinate system may be used for mapping textures to the model and is beneficial for the animation process as a whole. The data on UV coordinate system can be divided into regions of a defined size (e.g., 16×16).

At block **416**, the system can calculate blendshape coefficients for each frame of the of the input information (discreet or continuous). The system can calculate coefficients for each blendshape of model. The coefficients can be calculated for each region of the model. The calculated coefficients can be determined relative to a neutral state of the facial model. Deviation from the neutral state can be represented by a value different than zero. The coefficients can be calculated for each region in every frame of the input data.

At block **418**, the input model information is provided to the facial rig generation system **100** for generation of a new facial rig that corresponds to the expression information.

Example Flowchart—Frequency Separation

FIG. **5** is a flowchart of an example process **500** for performing a frequency separation subprocess that can be executed to generate a facial rig. For convenience, the process **500** will be described as being performed by a system of one or more computers (e.g., the facial rig generation system **100**).

At block **502**, optionally, the system can perform a principle component analysis (PCA) of the input scan information. The PCA can be used when the dataset is too large and needs to be reduced in order to efficiently execute the process. For example, in instances where the input model data is too big to fit in memory, such as may be the case with large animation sequences.

At block **504**, the system performs a frequency separation on each region. The frequency separation analysis can separate high frequency and low frequency data for each region. The frequency separation is performed on the production rig blendshapes and the input model blendshapes. The strength of the frequency separation can be adjusted based on various considerations, such as whether the output should be more like the scan or the rig, whether the output should be sharper or smoother, and/or other considerations. An example of the effects of different filter settings on a sample output is illustrated in FIG. **6**. A Laplacian filter may be used for the frequency separation.

At block **506**, the system solves a mesh deformation coefficient for the low frequency data. A linear least square solve can be performed for each region. In instances when PCA is used to for the input data, a projection on the data can be performed. The solve is performed on the low frequency data for the production rig and the input model data in order to calculate the mesh deformation coefficients. For similar expressions, coefficients of lower frequency data can be similar between the production rig and the input model data. This allows the system to essentially map the low frequency coefficients of the input scan data onto the low frequency coefficients of the production rig data.

At block **508**, the system applies the calculated low frequency coefficient to the high frequency data. The low frequency coefficients of the input scan data can be mapped to the low frequency coefficients of the production rig. Then the high frequency data can be used to generate a resulting mesh.

At block **510**, optionally, the input scan data can be interated upon to reduce the noise of the data. For example, the input scan data can be projected onto itself.

FIG. **6** illustrates an example **600** of the effects of the filter being used to analyze the data. Depending on the settings of the filter, the output for the model can be configured to be closer to the production rig or closer to the input scan data. Additionally, aspects of the filter can determine whether the output is smoother or sharper.

Example Flowchart—Optimization

FIG. **7** is a flowchart of an example process **700** for performing an optimization subprocess that can be executed to generate a facial rig. For convenience, the process **700** will be described as being performed by a system of one or more computers (e.g., the facial rig generation system **100**). The objective of the second subprocess is to optimize the result generated from the first subprocess to the production rig shape.

At block **702**, the system decomposes the calculated mesh for the input scan data into a direction and a magnitude. This provides for the ability to solve and weight each component differently.

At block **704**, optionally, the system can apply the magnitude from the production rig shape to the calculated mesh as initialization.

At block **706**, the direction and the magnitude are combined to generate an identity for the new facial rig. The direction can be the heavier weighted component in the solve and can be optimized more freely. The magnitude is set to converge slower since the goal is to maintain roughly the same region control of the production rig. For example, to avoid issues where the eyes are closing but another non-connected region such as the mouth is moving.

In one embodiment, the direction and magnitude can be optimized using the following algorithm:

$$y=\text{sum}\{(\text{Blendshape}*\text{Magnitude})*\text{coef}\}$$

At block **708**, the system can generate and output facial rig identity that corresponds to the input scan information. The output by the facial rig generation system **100** can be the blendshape of the model and corresponding solved animation based on the input scan corresponding to a new identity. The system does not change the rig logic used for controlling the facial rig.

Computing System

FIG. **8** illustrates an embodiment of computing device **10** according to the present disclosure. Other variations of the computing device **10** may be substituted for the examples explicitly presented herein, such as removing or adding components to the computing device **10**. The computing device **10** may include a game device, a smart phone, a tablet, a personal computer, a laptop, a smart television, a car console display, a server, and the like. As shown, the computing device **10** includes a processing unit **20** that interacts with other components of the computing device **10** and also external components to computing device **10**. A media reader **22** is included that communicates with media **12**. The media reader **22** may be an optical disc reader capable of reading optical discs, such as CD-ROM or DVDs, or any other type of reader that can receive and read data from game media **12**. One or more of the computing devices may be used to implement one or more of the systems disclosed herein.

Computing device **10** may include a separate graphics processor **24**. In some cases, the graphics processor **24** may be built into the processing unit **20**. In some such cases, the graphics processor **24** may share Random Access Memory (RAM) with the processing unit **20**. Alternatively, or in addition, the computing device **10** may include a discrete graphics processor **24** that is separate from the processing unit **20**. In some such cases, the graphics processor **24** may have separate RAM from the processing unit **20**. Computing device **10** might be a handheld video game device, a dedicated game console computing system, a general-purpose laptop or desktop computer, a smart phone, a tablet, a car console, or other suitable system.

Computing device **10** also includes various components for enabling input/output, such as an I/O **32**, a user I/O **34**, a display I/O **36**, and a network I/O **38**. I/O **32** interacts with storage element **40** and, through a device **42**, removable storage media **44** in order to provide storage for computing device **10**. Processing unit **20** can communicate through I/O **32** to store data, such as game state data and any shared data files. In addition to storage **40** and removable storage media **44**, computing device **10** is also shown including range of motion (Read-Only Memory) **46** and RAM **48**. RAM **48** may be used for data that is accessed frequently.

User I/O **34** is used to send and receive commands between processing unit **20** and user devices, such as game controllers. In some embodiments, the user I/O can include a touchscreen inputs. The touchscreen can be capacitive touchscreen, a resistive touchscreen, or other type of touchscreen technology that is configured to receive user input through tactile inputs from the user. Display I/O **36** provides input/output functions that are used to display images from the game being played. Network I/O **38** is used for input/output functions for a network. Network I/O **38** may be used during execution of a game.

Display output signals produced by display I/O **36** comprising signals for displaying visual content produced by computing device **10** on a display device, such as graphics, user interfaces, video, and/or other visual content. Computing device **10** may comprise one or more integrated displays configured to receive display output signals produced by display I/O **36**. According to some embodiments, display output signals produced by display I/O **36** may also be output to one or more display devices external to computing device **10**, such a display **16**.

The computing device **10** can also include other features that may be used with a game, such as a clock **50**, flash memory **52**, and other components. An audio/video player **56** might also be used to play a video sequence, such as a movie. It should be understood that other components may be provided in computing device **10** and that a person skilled in the art will appreciate other variations of computing device **10**.

Program code can be stored in range of motion **46**, RAM **48** or storage **40** (which might comprise hard disk, other magnetic storage, optical storage, other non-volatile storage or a combination or variation of these). Part of the program code can be stored in range of motion that is programmable (ROM, PROM, EPROM, EEPROM, and so forth), part of the program code can be stored in storage **40**, and/or on removable media such as game media **12** (which can be a CD-ROM, cartridge, memory chip or the like, or obtained over a network or other electronic channel as needed). In general, program code can be found embodied in a tangible non-transitory signal-bearing medium.

Random access memory (RAM) **48** (and possibly other storage) is usable to store variables and other game and processor data as needed. RAM is used and holds data that is generated during the execution of an application and portions thereof might also be reserved for frame buffers, application state information, and/or other data needed or usable for interpreting user input and generating display outputs. Generally, RAM **48** is volatile storage and data stored within RAM **48** may be lost when the computing device **10** is turned off or loses power.

As computing device **10** reads media **12** and provides an application, information may be read from game media **12** and stored in a memory device, such as RAM **48**. Additionally, data from storage **40**, range of motion **46**, servers accessed via a network (not shown), or removable storage media **46** may be read and loaded into RAM **48**. Although data is described as being found in RAM **48**, it will be understood that data does not have to be stored in RAM **48** and may be stored in other memory accessible to processing unit **20** or distributed among several media, such as media **12** and storage **40**.

It is to be understood that not necessarily all objects or advantages may be achieved in accordance with any particular embodiment described herein. Thus, for example, those skilled in the art will recognize that certain embodiments may be configured to operate in a manner that achieves or optimizes one advantage or group of advantages as taught herein without necessarily achieving other objects or advantages as may be taught or suggested herein.

All of the processes described herein may be embodied in, and fully automated, via software code modules executed by a computing system that includes one or more computers or processors. The code modules may be stored in any type of non-transitory computer-readable medium or other computer storage device. Some or all the methods may be embodied in specialized computer hardware.

Many other variations than those described herein will be apparent from this disclosure. For example, depending on the embodiment, certain acts, events, or functions of any of the algorithms described herein can be performed in a different sequence or can be added, merged, or left out altogether (for example, not all described acts or events are necessary for the practice of the algorithms). Moreover, in certain embodiments, acts or events can be performed concurrently, for example, through multi-threaded processing, interrupt processing, or multiple processors or processor cores or on other parallel architectures, rather than sequentially. In addition, different tasks or processes can be performed by different machines and/or computing systems that can function together.

The various illustrative logical blocks and modules described in connection with the embodiments disclosed herein can be implemented or performed by a machine, such as a processing unit or processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A processor can be a microprocessor, but in the alternative, the processor can be a controller, microcontroller, or state machine, combinations of the same, or the like. A processor can include electrical circuitry configured to process computer-executable instructions. In another embodiment, a processor includes an FPGA or other programmable device that performs logic operations without processing computer-executable instructions. A processor can also be implemented as a combination of computing devices, for example, a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration. Although described herein primarily with respect to digital technology, a processor may also include primarily analog components. For example, some or all of the signal processing algorithms described herein may be implemented in analog circuitry or mixed analog and digital circuitry. A computing environment can include any type of computer system, including, but not limited to, a computer system based on a microprocessor, a mainframe computer, a digital signal processor, a portable computing device, a device controller, or a computational engine within an appliance, to name a few.

Conditional language such as, among others, "can," "could," "might" or "may," unless specifically stated otherwise, are understood within the context as used in general to convey that certain embodiments include, while other embodiments do not include, certain features, elements and/or steps. Thus, such conditional language is not generally intended to imply that features, elements and/or steps are in any way required for one or more embodiments or that one or more embodiments necessarily include logic for deciding, with or without user input or prompting, whether these features, elements and/or steps are included or are to be performed in any particular embodiment.

Disjunctive language such as the phrase "at least one of X, Y, or Z," unless specifically stated otherwise, is understood with the context as used in general to present that an item, term, etc., may be either X, Y, or Z, or any combination thereof (for example, X, Y, and/or Z). Thus, such disjunctive language is not generally intended to, and should not, imply that certain embodiments require at least one of X, at least one of Y, or at least one of Z to each be present.

Any process descriptions, elements or blocks in the flow diagrams described herein and/or depicted in the attached figures should be understood as potentially representing modules, segments, or portions of code which include one or more executable instructions for implementing specific logical functions or elements in the process. Alternate implementations are included within the scope of the embodiments described herein in which elements or functions may be deleted, executed out of order from that shown, or discussed, including substantially concurrently or in reverse order, depending on the functionality involved as would be understood by those skilled in the art.

Unless otherwise explicitly stated, articles such as "a" or "an" should generally be interpreted to include one or more described items. Accordingly, phrases such as "a device configured to" are intended to include one or more recited devices. Such one or more recited devices can also be collectively configured to carry out the stated recitations. For example, "a processor configured to carry out recitations A, B and C" can include a first processor configured to carry out recitation A working in conjunction with a second processor configured to carry out recitations B and C.

It should be emphasized that many variations and modifications may be made to the above-described embodiments, the elements of which are to be understood as being among other acceptable examples. All such modifications and variations are intended to be included herein within the scope of this disclosure.

The following claims are example embodiments that are within the scope of this disclosure. The example embodiments that are listed should in no way be interpreted as limiting the scope of the embodiments. Various features of the example embodiments that are listed can be removed, added, or combined to form additional embodiments, which are part of this disclosure.

It should be understood that the original applicant herein determines which technologies to use and/or productize based on their usefulness and relevance in a constantly evolving field, and what is best for it and its players and users. Accordingly, it may be the case that the systems and methods described herein have not yet been and/or will not later be used and/or productized by the original applicant. It should also be understood that implementation and use, if any, by the original applicant, of the systems and methods described herein are performed in accordance with its privacy policies. These policies are intended to respect and prioritize player privacy, and to meet or exceed government and legal requirements of respective jurisdictions. To the extent that such an implementation or use of these systems and methods enables or requires processing of user personal information, such processing is performed (i) as outlined in the privacy policies; (ii) pursuant to a valid legal mechanism, including but not limited to providing adequate notice or where required, obtaining the consent of the respective user; and (iii) in accordance with the player or user's privacy settings or preferences. It should also be understood that the original applicant intends that the systems and methods described herein, if implemented or used by other entities, be in compliance with privacy policies and practices that are consistent with its objective to respect players and user privacy.

What is claimed:

1. A computer-implemented method comprising:

accessing a first facial rig having a rig topology, a first set of range of motion data of facial characteristics of the first facial rig, and a first set of calculated positional coefficients for the first set of range of motion data, wherein the first set of calculated positional coefficients define positions of the facial characteristics within the first facial rig, wherein the first facial rig has a first rig identity;

receiving input scan data comprising an input facial model and a plurality of facial expressions of facial characteristics of the input model, wherein the input facial model uses the topology of the first facial rig, wherein the input facial model has a facial model identity;

calculating positional coefficients of the input facial model for each of the plurality of facial expressions;

calculating frequency separation for a defined range of the motion data of the first facial rig resulting in first frequency data and second frequency data, wherein the first frequency data is higher than the second frequency data;

calculating frequency separation on each of the plurality of facial expressions of the input model resulting in third frequency data and fourth frequency data, wherein the third frequency data is higher than the fourth frequency data;

matching portions of the second frequency data to corresponding portions of the fourth frequency data, resulting in matched frequency data;

identifying third frequency data corresponding to the matched first low frequency data;

generating a mesh based on the third frequency data;

generating a second set of calculated positional coefficients associated with the input facial model identity; and

outputting a second facial rig having the rig topology, wherein the second facial rig is based at least in part on the mesh and the second set of calculated positional coefficients, wherein the second facial rig has a second rig identity that corresponds to the facial model identity of the input scan data, wherein the second set of calculated positional coefficients define positions of the facial characteristics within the second facial rig.

2. The computer-implemented method of claim **1**, wherein the input facial model is a three dimensional model.

3. The computer-implemented method of claim **2**, wherein the three dimensional model is based on two dimensional input data of a person.

4. The computer-implemented method of claim **1**, wherein the input facial model is composed of a plurality of blendshapes.

5. The computer-implemented method of claim **4** further comprising dividing the blendshapes into regions and calculating coefficients for each region in each of the plurality of expressions.

6. The computer-implemented method of claim **1**, wherein the coefficients correspond to displacement of the input model relative to a neutral state for each region of the input model.

7. The computer-implemented method of claim **1**, wherein the plurality of facial expressions of facial characteristics of the input model are a sequence of animations.

8. The computer-implemented method of claim **1** further comprising decomposing the input scan data into direction and magnitude.

9. The computer-implemented method of claim **8** further comprising combining the direction and magnitude to generate the second facial rig.

10. The computer-implemented method of claim **1** further comprising performing principle component analysis on input scan prior to calculating frequency separation.

11. The computer-implemented method of claim **1** further comprising calculating a final mesh deformation of the plurality of expressions using matrix multiplication based at least in part on the coefficients of the input facial model.

12. The computer-implemented method of claim **1**, wherein the frequency separation is calculated using a Laplacian filter.

13. A system comprising one or more processors and non-transitory computer storage media storing instructions that when executed by the one or more processors, cause the one or more processors to perform operations comprising:

accessing a first facial rig having a rig topology, a first set of range of motion data of facial characteristics of the first facial rig, and a first set of calculated positional coefficients for the first set of range of motion data, wherein the first set of calculated positional coefficients define positions of the facial characteristics within the first facial rig, wherein the first facial rig has a first rig identity;

receiving input scan data comprising an input facial model and a plurality of facial expressions of facial characteristics of the input model, wherein the input facial model uses the topology of the first facial rig, wherein the input facial model has a facial model identity;

calculating positional coefficients of the input facial model for each of the plurality of facial expressions;

calculating frequency separation for a defined range of the motion data of the first facial rig resulting in first frequency data and second frequency data, wherein the first frequency data is higher than the second frequency data;

calculating frequency separation on each of the plurality of facial expressions of the input model resulting in third frequency data and fourth frequency data, wherein the third frequency data is higher than the fourth frequency data;

matching portions of the second frequency data to corresponding portions of the fourth frequency data, resulting in matched frequency data;

identifying third frequency data corresponding to the matched frequency data;

generating a mesh based on the third frequency data;

generating a second set of calculated positional coefficients associated with the input facial model identity; and

outputting a second facial rig having the rig topology, wherein the second facial rig is based at least in part on the mesh and the second set of calculated positional coefficients, wherein the second facial rig has a second rig identity that corresponds to the facial model identity of the input scan data, wherein the second set of calculated positional coefficients define positions of the facial characteristics within the second facial rig.

14. The system of claim **13**, wherein the input facial model is composed of a plurality of blendshapes.

15. The system of claim **14** further comprising dividing the blendshapes into regions and calculating coefficients for each region in each of the plurality of expressions.

16. The system of claim **13**, wherein the coefficients correspond to displacement of the input model relative to a neutral state for each region of the input model.

17. The system of claim **13** further comprising decomposing input scan data into direction and magnitude.

18. The system of claim **17** further comprising combining the direction and magnitude to generate the second facial rig.

19. The system of claim **13** further comprising calculating a final mesh deformation of the plurality of expressions using matrix multiplication based at least in part on the coefficients of the input facial model.

20. A non-transitory computer storage medium storing instructions that when executed by one or more processors, cause the one or more processors to perform operations comprising:

accessing a first facial rig having a rig topology, a first set of range of motion data of facial characteristics of the first facial rig, and a first set of calculated positional coefficients for the first set of range of motion data, wherein the first set of calculated positional coefficients define positions of the facial characteristics within the first facial rig, wherein the first facial rig has a first rig identity;

receiving input scan data comprising an input facial model and a plurality of facial expressions of facial characteristics of the input model, wherein the input facial model uses the topology of the first facial rig, wherein the input facial model has a facial model identity;

calculating positional coefficients of the input facial model for each of the plurality of facial expressions;

calculating frequency separation for a defined range of the motion data of the first facial rig resulting in first frequency data and second frequency data, wherein the first frequency data is higher than the second frequency data;

calculating frequency separation on each of the plurality of facial expressions of the input model resulting in third frequency data and fourth frequency data, wherein the third frequency data is higher than the fourth frequency data;

matching portions of the second frequency data to corresponding portions of the fourth frequency data, resulting in matched frequency data;

identifying third frequency data corresponding to the matched frequency data;

generating a mesh based on the third frequency data;

generating a second set of calculated positional coefficients associated with the input facial model identity; and

outputting a second facial rig having the rig topology, wherein the second facial rig is based at least in part on the mesh and the second set of calculated positional coefficients, wherein the second facial rig has a second rig identity that corresponds to the facial model identity of the input scan data, wherein the second set of calculated positional coefficients define positions of the facial characteristics within the second facial rig.

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