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(54) **Title:** IMPROVED AUGMENTATION OF A VISUALISATION OF REALITY FOR FACIAL INJECTION

(57) **Abstract:** The present invention comprises a system, a method and a computer program product for augmenting a visualisation of reality for facial injection. Reference data from a head of a patient is obtained. The head comprises a face and anatomical structures. The reference data comprises facial data and structural data. An image of the face is recorded via a camera. A spatial map is determined based on the facial data and the image. A structural displacement is determined based on the spatial map and the structural data. The image is augmented on the basis of the structural displacement and represented via a visualisation tool. Via the determination of the structural displacement, a dynamic image can be dynamically augmented on the basis of a dynamically determined structural displacement. The anatomical structures can comprise blood vessels. The structural data can comprise blood vessel data. The structural displacement can comprise a vessel displacement.

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IMPROVED AUGMENTATION OF A VISUALISATION OF REALITY FOR FACIAL INJECTION

TECHNICAL FIELD

The invention relates to a system, a method and a computer program product for augmenting a visualisation of reality with additional information for facial injection.

PRIOR ART

US 2017/0 252 108 A1 describes a facial injection assist system comprising a visualisation system configured to display an augmented reality environment. The visualisation system can be augmented reality glasses. Patient-specific information about anatomical features (e.g. bones, nerves, blood vessels) of a patient being treated can be displayed via the visualisation system during an injection procedure. This can be obtained via a CT scan, an MRI scan, a photographic image, an X-ray image, and the like. The information displayed may relate to an intended zone. The information displayed may relate to an anatomical structure to be avoided. The information displayed can be aligned with the face of the patient face based on alignment points. The alignment points may relate to external anatomical features, such as a centre of an eye or a tip of a nose. The facial injection assist system may comprise a camera for recording the location of the alignment points during the injection procedure.

The document further describes repeatedly obtaining the anatomical features of a specific patient while deforming the face for determining muscles and muscle deformation for optimally determining an intended zone. As a result, the anatomical features must be obtained for each of a plurality of deformations. Furthermore, the document does not provide for linking of information of the face surface to underlying anatomical features. Moreover, the document does not provide for an adequate representation of anatomical features for a distortion not previously obtained.

The present invention aims to find a solution for at least some of the above problems.

SUMMARY OF THE INVENTION

In a first aspect, the present invention relates to a system for augmenting a visualisation of reality for facial injection, according to claim 1. In addition to facial injection, the system can also be used to augment a visualisation of reality for another medical or cosmetic treatment.

In a second aspect, the present invention relates to a method for augmenting a visualisation of reality for facial injection, according to claim 24. In addition to facial injection, the method can also be used to augment a visualisation of reality for another medical or cosmetic treatment.

In a third aspect, the present invention relates to a computer program product for augmenting a visualisation of reality for facial injection, according to claim 32. In addition to facial injection, the computer program product can also be used to augment a visualisation of reality for another medical or cosmetic treatment.

In a fourth aspect, the present invention relates to a use of a system according to the first aspect for determining a zone to be avoided in a cosmetic injection of a patient with a filler. The system according to the first aspect can be used for determining a zone to be avoided in an injection of a patient with a drug and/or autologous tissue.

In a fifth aspect, the present invention relates to a use of a method according to the second aspect for determining a zone to be avoided in a cosmetic injection of a patient with a filler. The method according to the second aspect can be used for determining a zone to be avoided in an injection of a patient with a drug and/or autologous tissue.

In a sixth aspect, the present invention relates to a use of a computer program product according to the third aspect for determining a zone to be avoided in a cosmetic injection of a patient with a filler. The computer program product according to the third aspect can be used for determining a zone to be avoided in an injection of a patient with a drug and/or autologous tissue.

Reference data from a head of a patient is obtained. The head comprises a face and anatomical structures. The reference data comprises facial data and structural data. Preferably, the anatomical structures comprise blood vessels. Preferably, the structural data comprises blood vessel data. Preferably, the facial data and structural data are obtained via magnetic resonance imaging (MRI) or computed tomography (CT). An image of the face is recorded via a camera. There may be an actual facial deformation between the face when determining the facial data and the face when determining the image. A spatial map is determined based on the facial data and the image. The spatial map is calculated from the facial data and the image. Preferably, the spatial map comprises a distortion representation. A structural displacement is determined based on the spatial map and the structural data. Preferably, the structural displacement comprises a vessel displacement. The image is augmented on the basis of the structural displacement and represented via a visualisation tool. Augmenting the image means, among other things, updating the image on the basis of the structural displacement, which represents the displacement of (parts of) anatomical structures, and updating the position of said (parts of) anatomical structures on the image. Preferably, the 'old' position of the anatomical structure is here omitted from the image, or adapted so that it becomes clear to a user from the visualisation what the updated position is.

The present invention is advantageous for various reasons. If reference data is obtained with a single spatial configuration of the head of a patient, the image can be correctly augmented for a plurality of spatial configurations, via the determination of the structural displacement. This not only results in a reduction in time and resources for obtainment, but also allows a visualisation of dynamically adapted anatomical structures to be projected over a dynamic image recording and thus form a dynamically augmented image. The augmentation of the image based on the structural displacement thus follows, in real time, changes in the recorded image, for example the position, orientation and facial expressions of the patient.

DESCRIPTION OF THE DRAWINGS

Figure 1 shows an illustrative representation of an anatomy of blood vessels.

Figure 2 shows an illustrative representation of a subdivision of a face via movement axes (joints).

Figure 3 shows an illustrative representation of anchor points in a face.

Figure 4 shows a schematic representation of a blood vessel, a skin and a bone.

DETAILED DESCRIPTION

The invention relates to a system, a method and a computer program product for augmenting a visualisation of reality for facial injection. The invention was summarised in the section provided for this purpose. In the following, the invention is described in detail, preferred embodiments are explained, and the invention is illustrated by way of examples.

Unless otherwise defined, all terms used in the description of the invention, including technical and scientific terms, have the meaning as commonly understood by a person skilled in the art to which the invention pertains. For a better understanding of the description of the invention, the following terms are explained explicitly.

In this document, 'a' and 'the' refer to both the singular and the plural, unless the context presupposes otherwise. For example, 'a segment' means one or more segments.

The terms 'comprise', 'comprising', 'consist of', 'consisting of', 'provided with', 'have', 'having', 'include', 'including', 'contain', 'containing' are synonyms and are inclusive or open terms that indicate the presence of what follows, and which do not exclude or prevent the presence of other components, features, elements, members and/or steps.

The term 'based on' and 'at least partially based on' are synonyms and are inclusive or open terms that indicate the presence of what follows, and which do not exclude or prevent the presence of other components, features, elements, members and/or steps.

The terms 'face' and 'countenance' are synonymous, and are to be interpreted within the present invention as the surface of the face or countenance.

An injection can be performed for cosmetic purposes. An injection can be performed for medical purposes. An injection can be an injection with a filler, a drug, an autologous tissue, or the like. An example of a drug is a toxin for reducing muscle pain and/or muscle contraction. An example of autologous tissue is fat. A non-exhaustive list of examples of fillers comprises Restylane, Perlane, Radiesse, Evolence, Prevelle Silk and Juvederm. A non-limitative example of a toxin is Azzalure (Dysport).

A ‘spatial map’ defines a spatial transformation. The transformation can comprise a translation. The transformation can comprise a rotation. The transformation can comprise a scaling. The transformation can be a non-isometric spatial transformation. The transformation can in particular be a shape-changing non-isometric spatial transformation.

The term ‘transformation’ describes the result of a shape-changing non-isometric spatial transformation. In a non-limiting illustrative example, a ‘spatial map’ may comprise a list of origin coordinates, e.g., reference anchor points, and corresponding target coordinates, e.g., anchor points in an image; or comprise a spatial transformation based on such a list. A ‘transformation’ occurs in this example when, according to the spatial map, an angle based on three points and/or a ratio of distances between pairs of points changes.

In a first aspect, the present invention relates to a system for augmenting a visualisation of reality for facial injection. In a second aspect, the present invention relates to a method for augmenting a visualisation of reality for facial injection. In a third aspect, the present invention relates to a computer program product for augmenting a visualisation of reality for facial injection. In a fourth aspect, the present invention relates to a use of a system according to the first aspect for determining a zone to be avoided in a cosmetic injection of a patient with a filler. In a fifth aspect, the present invention relates to a use of a method according to the second aspect for determining a zone to be avoided in a cosmetic injection of a patient with a filler. In a sixth aspect, the present invention relates to a use of a computer program product according to the third aspect for determining a zone to be avoided in a cosmetic injection of a patient with a filler.

The method according to the second aspect comprises various steps. The system according to the first aspect is configured to perform the steps of the method according to the second aspect. The computer program product according to the third aspect comprises instructions which, when the computer program product is executed by a computer system comprising a processor, a camera and a visualisation means, such as e.g. a system according to the first aspect, cause the computer system to execute the steps of the method according to the second aspect. A person having ordinary skill in the art will therefore appreciate that the different aspects of the present invention are related. Each feature described above or below may therefore relate to any of the aspects of the present invention, even if the feature is described in conjunction with a specific aspect.

Reference data from a head of a patient is obtained. The head comprises a face and anatomical structures. Preferably, the anatomical structures comprise blood vessels, fat pads, nerves and/or muscles. Preferably, the anatomical structures comprise blood vessels. Most preferably, the anatomical structures are blood vessels. The reference data comprises facial data and structural data and preferably also bone data. Preferably, the structural data comprises blood vessel data, fat pad data, nerve data and/or muscle data. Preferably, the structural data comprises blood vessel data. Most preferably, the structural data is blood vessel data. Preferably, the facial data and structural data are obtained via magnetic resonance imaging (MRI) or computed tomography (CT), or any other medical imaging technique, or combinations of two or more techniques. Based on this, it is possible – by combining spliced images from different sections – to produce a discrete three-dimensional representation of the head of a patient wherein said structures can be distinguished, also in discrete form. Preferably, at least bone data and blood vessel data are obtained via the imaging techniques, wherein these can be distinguished from each other and from other types of structures (wherein the other types of structures may or may not be further distinguishable from each other). In a possible embodiment, the reference data is obtained on the basis of two or more separate imaging techniques whose data is combined. This can be useful in situations in which certain structures need to be distinguished and visualised that are difficult to distinguish in a single technique. The way in which the reference data is obtained is possible via any imaging technique that is suitable for distinguishing the desired structures. The applicant notes that a large number of methods are known in the art for this purpose. Note that in the light of this invention, the method for obtaining the reference data is not so important, but rather that it is obtained.

Preferably, for example by means of MRI, CT, ultrasound, or angiography, the position of the blood vessels is determined in at least a part of the face, in the three-dimensional volume of the head. All detected structures are displayed in discrete, segmented voxels. Through the knowledge of the spatial position of each blood vessel, via the known position of the voxels that make up the blood vessel, the displacement of the blood vessels can easily be determined upon detection of facial deformation.

An image of the face is recorded via a camera. A non-exhaustive list of examples of cameras comprises a camera (on the back or front) of a smartphone, a camera connected to a desktop computer or laptop, and a camera of augmented reality glasses. A non-exhaustive list of augmented reality glasses comprises Microsoft HoloLens, Apple AR-glasses, Google AR-glasses and Oculus AR-glasses. There may be an actual facial distortion between the face when determining the facial data and

the face when determining the image. A spatial map is determined based on the facial data and the image. The spatial map is calculated from the facial data and the image. Preferably, the spatial map comprises a distortion representation. Preferably, the spatial map defines a shape-changing non-isometric spatial transformation. A structural displacement is determined based on the spatial map and the structural data. Preferably, the structural displacement comprises a blood vessel displacement, a fat pad displacement, a nerve displacement and/or a muscle displacement. Preferably, the structural displacement comprises a blood vessel displacement. Most preferably, the structural displacement is a blood vessel displacement. The image is augmented based on the structural displacement. The augmented image is displayed via a visualisation means.
The system comprises the camera and the visualisation means. An operator can then inject the patient based on the augmented image. This may involve cosmetic or aesthetic injection, for example with a filler. This can alternatively also involve medical injection, for example with a treatment substance.

Preferably, a user device comprising the camera and the visualisation means is provided. The user device can be augmented reality glasses. The user device can be a portable computer system. A non-exhaustive example list of portable computer systems comprises a smartphone, a tablet, and a laptop. In case the system comprises a user device, wherein the user device is a portable computer system, the system itself is preferably the portable computer system.

In a preferred embodiment of the first aspect of the invention, the system is configured for:

- obtaining reference data from a head of a patient, the head comprising bones, a face and anatomical structures, the reference data comprising bone data, facial data and structural data, wherein the anatomical structures are blood vessels and wherein the structural data is blood vessel data;
- recording an image of the face via the camera;
- determining a spatial map based on the facial data and the image;
- augmenting the image based on the map and the structural data, and preferably the bone data; wherein the augmentation of the image based on the map and the structural data, and preferably the bone data, visualises it when displaying the augmented image;
- displaying the augmented image via the visualisation means;

the system being further configured for:

- determining a structural displacement based on the map, the facial data, the bone data and the structural data; wherein the structural displacement involves a blood vessel displacement; and
- augmenting the image based on the structural displacement, wherein augmenting the image based on the structural displacement visualises the structural displacement when displaying the augmented image;

the structural displacement being determined by:

  - o determining a relative structural position d of a portion of the anatomical structures between a portion of the face and a portion of the bones based on the reference data;
  - o determining a facial deformation of the portion of the face relative to the portion of the bones based on the map;
  - o determining the structural displacement of the portion of the anatomical structures relative to the portion of the bones based on the facial deformation and the relative structural position.

In a preferred embodiment of the second aspect of the invention, the method comprises the steps of:

- obtaining reference data from a head of a patient, the head comprising bones, a face and anatomical structures, the reference data comprising bone data, facial data and structural data; and wherein the anatomical structures are blood vessels, wherein the structural data is blood vessel data;
- recording an image of the face via a camera;
- determining a spatial map based on the facial data and the image;
- augmenting the image based on the map and the structural data, and preferably the bone data; wherein the augmentation of the image based on the map and the structural data, and preferably the bone data, visualises it when displaying the augmented image;
- displaying the augmented image via a visualisation means;

wherein the step of augmenting the image based on the map and the structural data comprises the following steps:

- determining a structural displacement based on the map, the facial data, the bone data and the structural data; and wherein the structural displacement is a blood vessel displacement; and
- augmenting the image based on the structural displacement, wherein augmenting the image based on the structural displacement visualises the structural displacement when displaying the augmented image;

the structural displacement being determined by:

- determining a relative structural position d of a portion of the anatomical structures between a portion of the face and a portion of the bones based on the reference data;
- determining a facial deformation of the portion of the face relative to the portion of the bones based on the map;
- determining the structural displacement of the portion of the anatomical structures relative to the portion of the bones based on the facial deformation and the relative structural position.

In a preferred embodiment of the third aspect of the invention, the computer program performs the following steps:

- obtaining reference data from a head of a patient, the head comprising bones, a face and anatomical structures, the reference data comprising bone data, facial data and structural data;
- recording an image of the face via the camera;
- determining a spatial map based on the facial data and the image;
- augmenting the image based on the map and the structural data, and preferably the structural data; and preferably the bone data, wherein the augmentation of the image based on the map and the structural data, and preferably the bone data, visualises it when displaying the augmented image;
- displaying the augmented image via the visualisation means;

wherein the step of augmenting the image based on the map and the structural data comprises the following steps:

- determining a structural displacement based on the map and the structural data, wherein the structural displacement involves a blood vessel displacement; and
- augmenting the image based on the structural displacement, wherein augmenting the image based on the structural displacement visualises the structural displacement when displaying the augmented image; and

wherein the anatomical structures are blood vessels, wherein the structural data is blood vessel data;

the structural displacement being determined by:

- determining a relative structural position of a portion of the anatomical structures between a portion of the face and a portion of the bones based on the reference data;
- determining a facial deformation of the portion of the face relative to the portion of the bones based on the map;

- determining the structural displacement of the portion of the anatomical structures relative to the portion of the bones based on the facial deformation and the relative structural position.

In a further preferred embodiment of the aspects, the relative structural position d is the relative depth of the portion of the anatomical structures below the portion of the face relative to the depth of the portion of the bones below the portion of the face. In a still further preferred embodiment of the aspects, the structural displacement is determined on the basis of a flexibility ratio R, wherein the flexibility ratio of the portion of the anatomical structures is defined as (1 – d).

Figure 1 shows an illustrative representation of blood vessels in a head of a patient. With an intravascular injection with a filler, the corresponding blood vessel can become blocked. This can lead to skin necrosis, nerve paralysis, and even blindness when the blood vessel provided a supply to the eye. It is therefore essential to avoid blood vessels when injecting with a filler. Due to the dense network of blood vessels it is not easy to avoid them. Furthermore, the position of at least a portion of the blood vessels changes as the spatial configuration of the face changes, for example with changes in facial expression. Different persons may also have mutual differences in the anatomical position of the blood vessels. One of ordinary skill in the art will appreciate that for other intended medical or cosmetic injections the present invention can be used to augment an intended zone and/or a zone to be avoided in the image, depending on the case.

If reference data is obtained with a single spatial configuration of the head of a patient, the image can be correctly augmented for a plurality of spatial configurations, via the determination of the structural displacement based on the spatial map. This not only results in a reduction in time and resources for obtainment, but also allows a visualisation of dynamically adapted anatomical structures to be projected over a dynamic image recording and thus form a dynamically augmented image. The augmentation of the image based on the structural displacement thus follows, in real time, changes in the image, for example the position, orientation and facial expressions of the patient.

<u>Facial data</u>

In a preferred embodiment, a plurality of anchor points are determined in the image, and the spatial map is determined based on the facial data and the plurality of anchor points in the image. Preferably, vis-à-vis the anchor points, the three-dimensional position information of the anchor points is recorded in the image.

The facial data can comprise reference anchor points. The facial data can comprise three-dimensional spatial facial information. Reference anchor points can be determined based on the three-dimensional spatial facial information. The spatial map can be determined based on the reference anchor points and the plurality of anchor points in the image.

Preferably, the structural data is determined based on data obtained via medical imaging, such as e.g. MRI or CT. Preferably, the facial data comprises reference anchor points. Preferably, the reference anchor points are determined based on the structural data.

In a preferred embodiment, the facial data comprises a subdivision into movement axes (joints). Preferably, each of the movement axes comprises a weight. A rigging based on a subdivision into movement axes can define a predetermined deformation capacity. Preferably, the facial data comprises reference anchor points and movement axes between the reference anchor points. With well-chosen anchor points and intermediate movement axes, this defined deformation capacity corresponds to the natural deformation capacity. **Figure 2** shows an illustrative representation of a subdivision of a face via movement axes.

Preferably, the plurality of anchor points comprises at least 10 anchor points, more preferably at least 20 anchor points, even more preferably at least 30 anchor points, even more preferably at least 45 anchor points, and most preferably at least 60 anchor points.

A non-exhaustive list of examples of anchor points comprises an anchor point on a chin; an anchor point on a lip; an anchor point at a corner of the mouth (left and/or right corner of the mouth); an anchor point on a nose; an anchor point on an eyelid (e.g., medial and/or lateral canthus); an anchor point on an ear; and an anchor point on an eyebrow. Preferably, the plurality of anchor points comprises at least two, preferably at least three, more preferably at least four, even more preferably at least five, even more preferably at least six, and most preferably all seven, of the anchor points of the non-exhaustive list of examples of anchor points.

The anchor points are typically easily recognisable points on a face, preferably allowing them to be recognised automatically by the system itself – although manual indication and/or correction is also possible in situations with a limited number of anchor points.

In a possible embodiment, certain anchor points are defined on (a ‘historical’ image based on) reference data previously obtained. When recording an image of the face via the camera, an overlay of the historical image is created on the recorded image, wherein a mapping is determined which determines the transformation between the historical and the recorded image, and in particular records the displacement of anchor points. Note that the historical image does not necessarily have to be effectively created here, since it can also be done in reverse and the recorded image is converted into ‘momentary’ reference data and an inverse mapping can be determined with respect to the previously obtained reference data in order to thus record the deformations (whether or not via anchor points). Both options, however, fall under the same principle.

Figure 3 shows an illustrative representation of a plurality of anchor points in a face. The reference anchor points are determined on the basis of the structural data, which is preferably obtained via a medical imaging technique such as MRI or CT. These reference anchor points are patient-specific. The plurality of anchor points in this example comprises 68 anchor points. Points **1** and **17** concern, for example, anchor points on an ear helix. Point **2** concerns, for example, an anchor point on the ear antitragus. Point **3** concerns, for example, an anchor point on an earlobe. Point **9** concerns, for example, an anchor point on a chin. Points **18**, **22**, **23** and **27** concern, for example, anchor points on an eyebrow. Points **37**, **40**, **43** and **46** concern, for example, anchor points on an eyelid. Point **28** concerns, for example, an anchor point on a nasal bridge. Point **31** concerns, for example, an anchor point on a tip of the nose. Points **32** and **36** concern, for example, anchor points at an attachment of a nostril. Points **49**, **50**, **55**, **60**, **61** and **68** concern, for example, anchor points on a contour of an upper or lower lip.

WO 2003/023 713 A1 and references cited therein describe further illustrative information regarding the determination of a spatial map for a face.

Anatomical structural data

In a preferred embodiment, the structural data comprises three-dimensional spatial anatomical structure information. Preferably, the spatial anatomical structure information comprises spatial blood vessel information, spatial fat pad information, spatial nerve information and/or spatial muscle information. Preferably, the spatial anatomical structure information comprises spatial blood vessel information. Most preferably, the spatial anatomical structure information is spatial blood vessel information.

In a preferred embodiment, the structural data comprises a three-dimensional spatial mesh.

In a preferred embodiment, a point cloud comprising spatial anatomical structure information is obtained. The mesh can be determined based on the point cloud. The point cloud can be obtained via medical imaging, such as ultrasound, angiography, infrared imaging, magnetic resonance imaging (MRI) or computed tomography (CT), such as dual-energy CT. CT has the advantage that it is faster than MRI, resulting in a faster obtainment, and consequently a smaller possible discrepancy between the facial data and the structural data due to movement of the patient. As a result, the augmentation of the image is of significantly higher quality and the patient experiences considerably less discomfort. In addition, it allows metallic artefacts, such as braces and crowns, to be suppressed using software. Most preferably, the point cloud is obtained via MRI. The point cloud can be obtained via MRI with the administration of no, one or more intravenous contrast mediums. Most preferably, the point cloud is obtained via MRI without administration of an intravenous contrast medium or any addition to improve the quality of the representation of the anatomical structures. MRI has the advantage that no radiological radiation is involved. Preferably, MRI is performed without administration of an intravenous contrast medium. Possible allergic reactions and complications due to an infusion are thus avoided.

In a preferred embodiment, the point cloud comprising spatial anatomical structure information is obtained via:

- exposing the patient, preferably the head, to an extracorporeal heat source, preferably an infrared lamp;

- preferably, stimulating muscles of the patient, preferably muscles in the head, preferably by stimulation of the muscles by the patient, more preferably by voluntary stimulation of the muscles by the patient; and
- subsequently obtaining the point cloud comprising spatial anatomical structure information via magnetic resonance imaging, in particular magnetic resonance angiography.

The same embodiment can be used for the visualisation of one or more anatomical structures of another body part. A non-exhaustive example list of other body parts comprises an arm, a leg, a hand, a foot. Analogous steps for the stimulation of muscles in the relevant body part can then be followed.

The visualisation of human vessels by means of a medical imaging system depends mainly on the flow and the calibre (diameter) of the vessels. A vessel can be an artery, a vein, a lymph vessel or any other tubular anatomical structure in the human body, such as, for example, a vascular prosthesis. The greater the flow rate and/or the calibre, the better a vessel is visible through a medical imaging technique.

In a preferred embodiment, the point cloud comprising spatial anatomical structure information is obtained without administration of an intravenous contrast medium, without administration of a drug, and without X-rays. This is advantageous to avoid health risks to the patient. Magnetic resonance angiography (MRA) offers this possibility.

An example of an embodiment is explained in this section. To perform MRA, the patient is placed in front of an extracorporeal heat source, such as, for example, an infrared lamp, which is determined by the type of examination and/or the body part, such as, for example, 30 cm away from the face, parallel to the face, and for 10 minutes, for blood vessels in the face. This induces vasodilation and an increased flow. During this exposure, the patient is asked to activate muscles of the examined anatomical region, e.g., activating facial muscles by forming different facial expressions, such as frowning and smiling. By activating the muscles, such as muscles in the face, a leg or an arm, blood flow through the blood vessels of the examined anatomical region is increased, which further improves their visibility via MRA. Furthermore, the blood flow is also increased by the body itself, namely to remove heat from the relevant anatomical region. This considerably improves the visualisation of vessels in the examined anatomical region. Immediately following this specific preparation, an MRA image recording of the anatomical region is realised, which can be specifically adjusted based on the aforementioned preparation steps and/or the specific anatomical region.

In a preferred embodiment, the structural data comprises a subdivision into movement axes. Preferably, the structural data comprises a subdivision of the mesh into motion axes. Preferably, each of the movement axes comprises a weight.

In a preferred embodiment, a spatial annotation map is determined of the structural data, preferably the mesh, on a template, the template comprising annotation information. The motion axes, and preferably also the weight for each of the motion axes, is then determined based on the spatial annotation map and the annotation information of the template.

In a preferred embodiment, a flexibility ratio is determined for a portion of the anatomical structures based on a dimension of the portion of the anatomical structures, a location of the portion of the anatomical structures, and annotation information of the template corresponding to the spatial annotation map and the portion of the anatomical structures.

In a preferred embodiment, determining a structural displacement based on the spatial map and the structural data is determining a mesh deformation based on the spatial map and the mesh. The image is then augmented based on a two-dimensional projection of at least a portion of the mesh deformation.

Displacement

In a preferred embodiment, the head comprises bones (e.g., the bone structure of the skull) and the reference data comprises bone data. In this embodiment, the system is configured to determine a structural displacement based on the spatial map, the structural data, the facial data, and the bone data. Other data can also contribute to this. The structural displacement is then determined based on the aforementioned data and other data. For example, a blood vessel displacement can be determined based on structural data comprising blood vessel data as well as data regarding other anatomical structures, such as, for example, structural data comprising blood vessel data, fat pad data, and muscle data.

In a preferred embodiment, the bone data comprises three-dimensional spatial bone information.

In a preferred embodiment, the bone data comprises a subdivision into movement axes. Preferably, each of the movement axes comprises a weight.

In a preferred embodiment, a relative structural position of a portion of the anatomical structures between a portion of the face and a portion of the bones is determined based on the reference data. Preferably, the relative structural position is the relative depth of the portion of the anatomical structures below the portion of the face relative to the depth of the portion of the bones below the portion of the face. A facial deformation, for example as a result of facial expression via the facial muscles, i.e. a lateral or medial movement and/or cranial or caudal movement, of the portion of the face relative to the portion of the bones is determined based on the spatial map. Preferably, a flexibility ratio is determined for the portion of the anatomical structures based on the relative structural position. A structural displacement of the portion of the anatomical structures relative to the portion of the bones is determined based on the facial deformation and the relative structural position. Preferably, a structural displacement of the portion of the anatomical structures relative to the portion of the bones is determined based on the facial deformation and the flexibility ratio. The image is augmented based on the structural displacement of the portion of the anatomical structures.

In particular for blood vessels, the structural displacement appears to be very strongly linked to the relative depth of the anatomical structure. While the underlying bones are substantially rigid, and the overlying face portion is flexible (allows deformation), the blood vessels are in an area anchored on one side to the underlying bones, and anchored on the other side to the overlying skin, causing the deformation of the skin to take place averaged out on the blood vessels, depending on the relative distances between blood vessel and skin on the one hand, and blood vessel and bones on the other hand. The above also applies to other (flexible) anatomical structures, such as fat pads, nerves, muscles. By making use of the (objectively) traceable and quantifiable displacement/deformation of the face, being the outer layer of the head, preferably on the basis of anchor points, the displacement effect on underlying anatomical structures, i.e. the structural displacement, can be determined.
An additional advantage is that a large part of the medical imaging methods, and in particular the more accessible ones, very easily allow blood vessels to be detected

very accurately in view of their more deviating features compared to other structures/material between face and leg.

In a specific preferred embodiment, use is conveniently made of the fact that the reference data is typically obtained by combining 2D images into a discrete 3D representation (e.g. via separate – parallel – images or slices of an MRI, CT scan, ultrasound or angiography, but not limited to that). This discretisation into full-volume voxels allows the structural displacement of an anatomical structure to be carried out in a discrete manner, wherein the anatomical structure is segmented into the voxels, and for each voxel the displacement is determined separately on the basis of a relative structural position of the voxel, and in particular the relative depth, wherein it is determined based on the distance of the voxel from the face (area thereof), and an underlying bone structure. By discretely determining the structural displacement (i.e. per portion of the structure, and not for the entire structure itself), minute and very local deformations can be determined very accurately. On the basis of annotation data, any errors can then still be corrected, such as ensuring that voxels that belong to the same anatomical structure remain grouped.

It is crucial for a treating physician to know the position of all underlying anatomical structures as accurately as possible, in order to prevent problems in which substances are injected into an inappropriate anatomical structure (e.g. filler into a blood vessel).

In a preferred embodiment, the relative structural position (of the portion of the anatomical structures below the face) is the relative depth thereof relative to the depth of the portion of the bones below the portion of the face. This is possible because the structural data, and in particular the bone data, facial data and the blood vessel data, are provided with three-dimensional position information thereof in the obtained reference data. Building further on the simple detection of facial deformation, typically with the help of anchor points, the effective structural displacement can then also be determined based on the relative structural position.

In a further preferred embodiment, the structural displacement can be determined on the basis of a flexibility ratio R, the flexibility ratio being defined as (1-d).

Figure 4 shows an illustrative schematic representation of a blood vessel (402), a skin (401) and a bone (403). The distance from the blood vessel to the skin is $\mathbf{D_h}$.

The distance from the blood vessel to the bone is $\mathbf{D_b}$. A relative structural position of a portion of the anatomical structures, in this example the blood vessel (402), between a portion of the face, in this example the skin (401), and a portion of the bones, in this example the bone (403), is determined. The relative structural position **d** in this example is the relative depth of the blood vessel (402) below the skin (401) relative to the depth of the bone (403) below the skin (401): $\mathbf{d = D_h / (D_h + D_b)}$. A facial displacement **A** of the portion of the face (401) relative to the portion of the bones (403) is determined based on the spatial map. A structural displacement **F** of the portion of the anatomical structures relative to the portion of the bones is determined on the basis of the facial deformation and the relative structural position, in particular the relative depth of the blood vessel: $\mathbf{F = (1-d)\ A}$. Based on the relative depth of the portion of the anatomical structures, a flexibility ratio **R** can be defined, namely $\mathbf{R = (1-d)}$, which is the ratio of: the displacement of the blood vessel relative to the bone **F**; and the displacement of the skin relative to bone **A**, namely $\mathbf{R = F / A = (1-d)}$.

In a preferred embodiment the template comprises a subdivision into zones and the annotation information of the template per zone comprises a mathematical deformation model. Any mathematical deformation model can herein consider features of tissue structures of the zone.

<u>Dynamic image</u>

In a preferred embodiment, the image is a dynamic image, a real-time image. A sequence of images can be recorded at a predetermined frequency. One of ordinary skill in the art will appreciate that ‘real time’ in this document means that the relevant corresponding steps are repeatedly performed at said predetermined frequency for each image of the sequence, and preferably without visible delay for an operator. The dynamic image is dynamically augmented based on a dynamically determined structural displacement. A structural displacement can be determined in real time for each image of the sequence of images, on the basis of which the image is augmented and displayed via the visualisation means.

In a preferred embodiment, the following steps are performed iteratively, with n initially 1 and increasing by 1 after an iteration. An nth image of the face is recorded via the camera. An nth spatial map is determined based on the nth image and the (n-1)th image, the 0th image being the facial data. An nth structural displacement is determined based on the nth map and the (n-1)th structural displacement, the

0th structural displacement being the structural data. The nth image is augmented based on the nth structural displacement. The augmented nth image is displayed via the visualisation means. In this embodiment, a spatial map is determined based on two consecutive images of the sequence, on the basis of which a structural displacement corresponding to the earlier image of the two consecutive images is converted into a new structural displacement.

In a preferred embodiment, the system is configured to determine a size of the nth map. The nth structural displacement is the (n-1)th structural displacement in case the size of the nth map is smaller than a predetermined dimension. With sufficiently small changes in the image, no new structural displacement needs to be determined, which results in a considerably longer operating capacity for user devices with a battery, since the processor has to perform fewer operations.

CLAIMS

1. System for augmenting a visualisation of reality for facial injection, the system comprising a camera and a visualisation means, the system being configured for:
   - obtaining reference data from a head of a patient, the head comprising bones, a face and anatomical structures, the reference data comprising bone data, facial data and structural data, wherein the anatomical structures are blood vessels and wherein the structural data is blood vessel data;
   - recording an image of the face via the camera;
   - determining a spatial map based on the facial data and the image;
   - augmenting the image based on the map and the structural data, and preferably the bone data; wherein the augmentation of the image based on the map and the structural data, and preferably the bone data, visualises it when displaying the augmented image;
   - displaying the augmented image via the visualisation means,

   characterised in that the system is configured for:
   - determining a structural displacement based on the map, the facial data, the bone data and the structural data; wherein the structural displacement involves a blood vessel displacement; and
   - augmenting the image based on the structural displacement, wherein augmenting the image based on the structural displacement visualises the structural displacement when displaying the augmented image;

   the structural displacement being determined by:
     - determining a relative structural position d of a portion of the anatomical structures between a portion of the face and a portion of the bones based on the reference data;
     - determining a facial deformation of the portion of the face relative to the portion of the bones based on the map;
     - determining the structural displacement of the portion of the anatomical structures relative to the portion of the bones based on the facial deformation and the relative structural position.

2. System according to the preceding claim 1, wherein the relative structural position d is the relative depth of the portion of the anatomical structures

below the portion of the face relative to the depth of the portion of the bones below the portion of the face.

3. System according to preceding claim 2, wherein the structural displacement is determined on the basis of a flexibility ratio R, wherein the flexibility ratio of the portion of the anatomical structures is defined as (1 − d).

4. System according to any of the preceding claims, wherein the system is configured for:
   - determining a plurality of anchor points in the image; and
   - determining the map based on the facial data and the plurality of anchor points in the image.

5. System according to the preceding claim 4, wherein the plurality of anchor points comprises at least 10 anchor points, preferably at least 20 anchor points, more preferably at least 30 anchor points, even more preferably at least 45 anchor points, most preferably at least 60 anchor points.

6. System according to any of the preceding claims 4 and 5, wherein the plurality of anchor points comprises at least two, preferably at least three, more preferably at least four, even more preferably at least five, even more preferably at least six, and most preferably all seven, of the following anchor points: an anchor point on a chin; an anchor point on a lip; an anchor point at a corner of the mouth; an anchor point on a nose; an anchor point on an eyelid; an anchor point on an ear; and an anchor point on an eyebrow.

7. System according to any of the preceding claims, wherein the facial data comprises a subdivision into motion axes, preferably wherein each of the motion axes comprises a weight.

8. System according to any of the preceding claims, wherein the structural data comprises a subdivision into motion axes, preferably wherein each of the motion axes comprises a weight.

9. System according to any of the preceding claims and according to preceding claim 2, wherein the bone data comprises a subdivision into movement axes, preferably wherein each of the movement axes comprises a weight.

10. System according to any of the preceding claims, wherein the structural data comprises a three-dimensional spatial mesh.

11. System according to the preceding claim 10, wherein the system is configured for:
   - obtaining a point cloud comprising spatial anatomical structure information;
   - determining the mesh based on the point cloud.

12. System according to the preceding claim 11, wherein the point cloud comprising spatial anatomical structure information is obtained via magnetic resonance imaging or computer tomography, preferably magnetic resonance imaging.

13. System according to any of preceding claims 11 and 12, wherein the point cloud comprising spatial anatomical structure information is obtained via:
   - exposing the patient, preferably the head, to an extracorporeal heat source, preferably an infrared lamp;
   - preferably, stimulating muscles of the patient, preferably muscles in the head, more preferably by stimulation of the muscles by the patient, even more preferably by voluntary stimulation of the muscles by the patient; and
   - subsequently obtaining the point cloud comprising spatial anatomical structure information via magnetic resonance imaging, in particular magnetic resonance angiography.

14. System according to any of the preceding claims 11 and 13, wherein the point cloud comprising spatial anatomical structure information is obtained without administration of an intravenous contrast substance, without administration of a drug, and without X-rays.

15. System according to the preceding claim 8 and according to any of the preceding claims 10 to 14, wherein the system is configured for:
   - determining a spatial annotation map of the mesh on a template, the template comprising annotation information;
   - determining the motion axes, and preferably the weight for each of the motion axes, based on the annotation map and the annotation information of the template.

16. System according to the preceding claim 15, wherein the system is configured for determining a flexibility ratio for a portion of the anatomical structures based on a dimension of the portion of the anatomical structures, a location of the portion of the anatomical structures, and annotation information of the template corresponding to the annotation map and the portion of the anatomical structures.

17. System according to any of preceding claims 10 to 16, wherein determining a structural displacement based on the map and the structural data is the step of determining a mesh deformation based on the map and the mesh, and wherein augmenting the image based on the structural displacement is the step of augmenting the image based on a two-dimensional projection of at least a portion of the mesh deformation.

18. System according to any of the preceding claims, wherein the image is a dynamic image, and wherein the dynamic image is dynamically augmented based on a dynamically determined structural displacement.

19. System according to any of the preceding claims, wherein the system is configured for iteratively, with n initially 1 and increasing by 1 after an iteration:
   - recording an nth image of the face via the camera;
   - determining an nth spatial map based on the nth image and the (n-1)th image, the 0th image being the facial data;
   - determining an nth structural displacement based on the nth map and the (n-1)th structural displacement, wherein the 0th structural displacement is the structural data;
   - augmenting the nth image based on the nth structural displacement; and
   - displaying the augmented nth image via the visualisation means.

20. System according to the preceding claim 19, wherein the system is configured to determine a size of the nth map, and wherein the nth structure displacement is the (n-1)th structure displacement in case the size of the nth map is smaller than a predetermined limit value.

21. System according to any of the preceding claims, wherein the system comprises a user device comprising the camera and the visualisation means, wherein the user device is augmented reality glasses or a portable computer system, preferably wherein the portable computer system is a smartphone, a tablet or a laptop.

22. Method for augmenting a visualisation of reality for facial injection, the method comprising the steps of:
   – obtaining reference data from a head of a patient, the head comprising bones, a face and anatomical structures, the reference data comprising bone data, facial data and structural data; and wherein the anatomical structures are blood vessels, wherein the structural data is blood vessel data;
   – recording an image of the face via a camera;
   – determining a spatial map based on the facial data and the image;
   – augmenting the image based on the map and the structural data, and preferably the bone data; wherein the augmentation of the image based on the map and the structural data, and preferably the bone data, visualises it when displaying the augmented image;
   – displaying the augmented image via a visualisation means,

characterised in that the step of augmenting the image based on the map and the structural data comprises the following steps:
   – determining a structural displacement based on the map, the facial data, the bone data and the structural data; and wherein the structural displacement is a blood vessel displacement; and
   – augmenting the image based on the structural displacement, wherein augmenting the image based on the structural displacement visualises the structural displacement when displaying the augmented image;

the structural displacement being determined by:
   - determining a relative structural position d of a portion of the anatomical structures between a portion of the face and a portion of the bones based on the reference data;
   - determining a facial deformation of the portion of the face relative to the portion of the bones based on the map;
   - determining the structural displacement of the portion of the anatomical structures relative to the portion of the bones

based on the facial deformation and the relative structural position.

23. Method according to preceding claim 22, comprising the step of cosmetically injecting the patient with a filler based on the augmented image by an operator.

24. Method according to any of preceding claims 22 and 23, wherein the relative structural position d is the relative depth of the portion of the anatomical structures below the portion of the face relative to the depth of the portion of the bones below the portion of the face.

25. Method according to the preceding claim 24, wherein the structural displacement is determined on the basis of a flexibility ratio R, wherein the flexibility ratio of the portion of the anatomical structures is defined as (1 – d).

26. Method according to any of preceding claims 22 to 25, wherein the structure data comprises a three-dimensional spatial mesh.

27. Method according to the preceding claim 26, wherein the method comprises the steps of obtaining a point cloud comprising spatial anatomical structure information; and determining the mesh based on the point cloud.

28. Method according to preceding claim 27, wherein the point cloud comprising spatial anatomical structure information is obtained via:
   - exposing the patient, preferably the head, to an extracorporeal heat source, preferably an infrared lamp;
   - preferably, stimulating muscles of the patient, preferably muscles in the head, more preferably by stimulation of the muscles by the patient, even more preferably by voluntary stimulation of the muscles by the patient; and
   - subsequently obtaining the point cloud comprising spatial anatomical structure information via magnetic resonance imaging, in particular magnetic resonance angiography.

29. Method according to any of preceding claims 27 and 28, wherein the point cloud comprising spatial anatomical structure information is obtained without

administration of an intravenous contrast substance, without administration of a drug, and without X-rays.

30. Computer program product for augmenting a visualisation of reality for facial injection, the computer program product comprising instructions which, when the computer program product is executed by a computer system comprising a processor, a camera and a visualization means, cause the computer system to perform the following steps:
    - obtaining reference data from a head of a patient, the head comprising bones, a face and anatomical structures, the reference data comprising bone data, facial data and structural data;
    - recording an image of the face via the camera;
    - determining a spatial map based on the facial data and the image;
    - augmenting the image based on the map and the structural data, and preferably the structural data; and preferably the bone data, wherein the augmentation of the image based on the map and the structural data, and preferably the bone data, visualises it when displaying the augmented image;
    - displaying the augmented image via the visualisation means,

    characterised in that the step of augmenting the image based on the map and the structural data comprises the following steps:
    - determining a structural displacement based on the map and the structural data, wherein the structural displacement involves a blood vessel displacement; and
    - augmenting the image based on the structural displacement, wherein augmenting the image based on the structural displacement visualises the structural displacement when displaying the augmented image; and

    wherein the anatomical structures are blood vessels, wherein the structural data is blood vessel data;

    the structural displacement being determined by:
        - determining a relative structural position of a portion of the anatomical structures between a portion of the face and a portion of the bones based on the reference data;
        - determining a facial deformation of the portion of the face relative to the portion of the bones based on the map;
        - determining the structural displacement of the portion of the anatomical structures relative to the portion of the bones

based on the facial deformation and the relative structural position.

31. Computer program product according to the preceding claim 30, wherein the relative structural position d is the relative depth of the portion of the anatomical structures below the portion of the face relative to the depth of the portion of the bones below the portion of the face.

32. Computer program product according to the preceding claim 31, wherein the structural displacement is determined based on a flexibility ratio R, wherein the flexibility ratio of the portion of the anatomical structures is defined as $(1 - d)$.

33. Computer program product according to any of the preceding claims 30 to 32, wherein the structural data comprises a three-dimensional spatial mesh.

34. Computer program product according to the preceding claim 33, wherein the computer program product is configured for:
   - obtaining a point cloud comprising spatial anatomical structure information;
   - determining the mesh based on the point cloud.

35. Computer program product according to the preceding claim 34, wherein the point cloud comprising spatial anatomical structure information is obtained via:
   - exposing the patient, preferably the head, to an extracorporeal heat source, preferably an infrared lamp;
   - preferably, stimulating muscles of the patient, preferably muscles in the head, more preferably by stimulation of the muscles by the patient, even more preferably by voluntary stimulation of the muscles by the patient; and
   - subsequently obtaining the point cloud comprising spatial anatomical structure information via magnetic resonance imaging, in particular magnetic resonance angiography.

36. Computer program product according to any of preceding claims 34 and 35, wherein the point cloud comprising spatial anatomical structure information

is obtained without administration of an intravenous contrast substance, without administration of a drug, and without X-rays.

37. Use of a system according to any of the preceding claims 1 to 21 for determining a zone to be avoided in a cosmetic injection of a patient with a filler.

38. Use of a method according to any of the preceding claims 22 to 29 for determining a zone to be avoided in a cosmetic injection of a patient with a filler.

39. Use of a computer program product according to any of the preceding claims 30 to 36 for determining a zone to be avoided in a cosmetic injection of a patient with a filler.

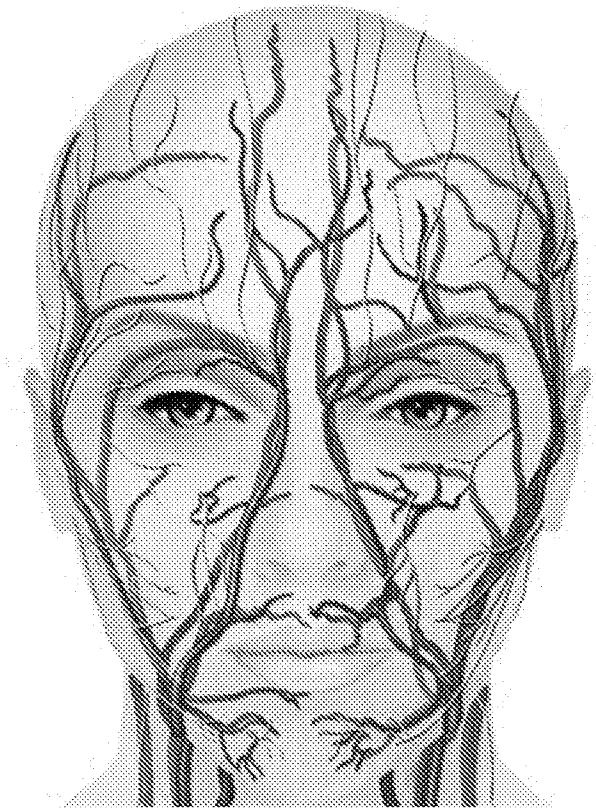

Fig. 1

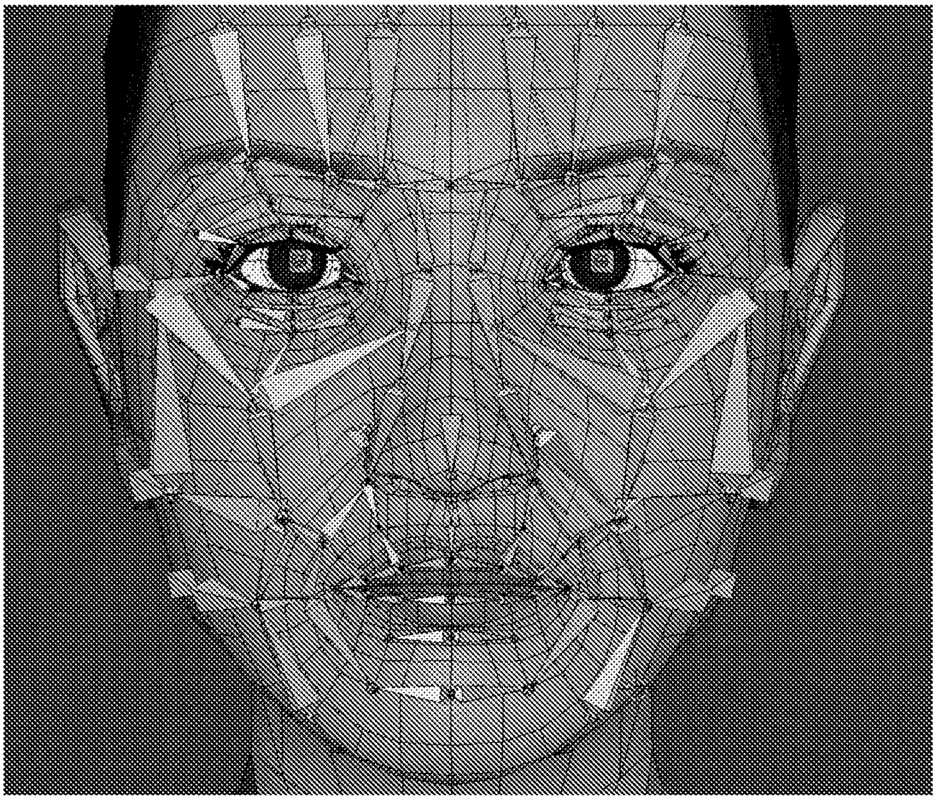

Fig. 2

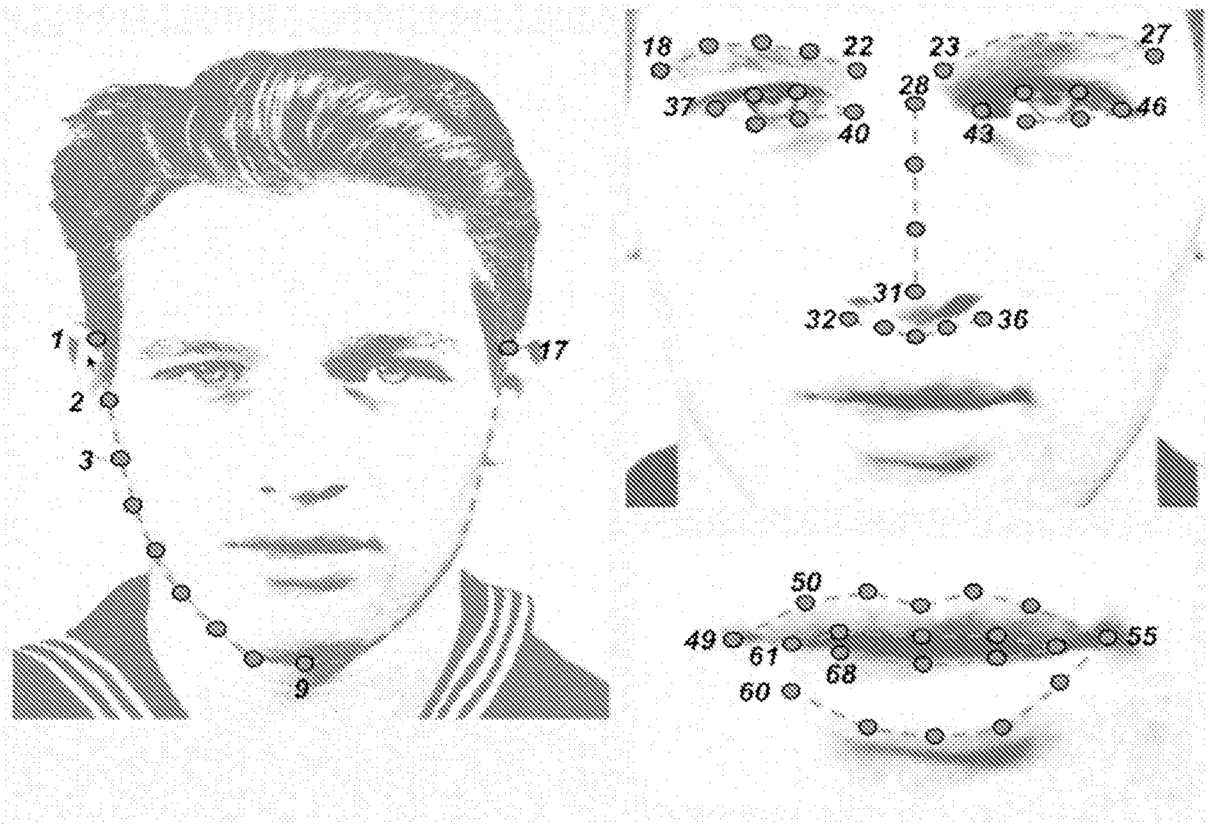
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Fig. 3

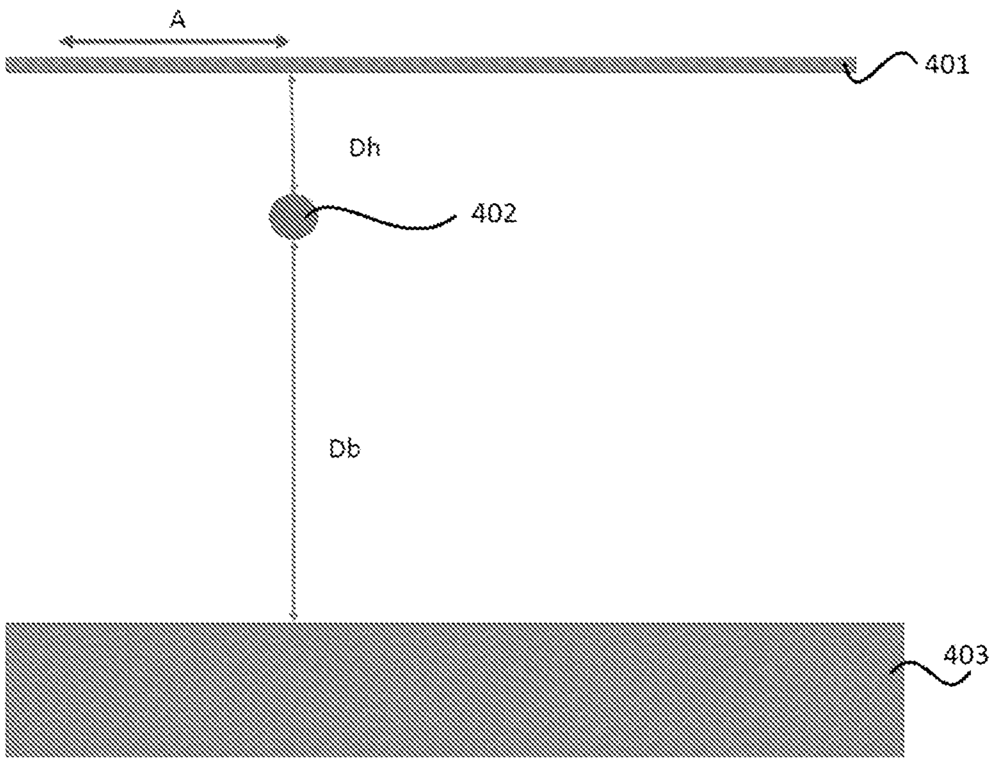
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Fig. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2020/051386

A. CLASSIFICATION OF SUBJECT MATTER
INV. G16H20/40 G16H30/40
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G16H

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

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

EPO-Internal, BIOSIS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 May 2020	19/05/2020

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Vogt, Titus

Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	US 2015/272691 A1 (KIM JONG MIN [US] ET AL) 1 October 2015 (2015-10-01) paragraphs [0011], [0025], [0036]; claims	1-39
Y	EP 2 258 265 A2 (MINIMEDREAM CO LTD [KR]) 8 December 2010 (2010-12-08) paragraphs [0071], [0045], [0033], [0026]; claims; figures	1-39
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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