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(54) [trilingual:] **PROCESS AND DEVICE FOR COMPUTER-ASSISTED RESTORATION OF TEETH**

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EP-A-0 373 077 **US-A-4 575 805**

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Description

[0001] US-PS 4 575 805 describes a method and a device working according to said method for the computer-assisted restoration of teeth, in which in a first step initially the geometry of the tooth to be restored and perhaps its surroundings, i.e. also the opposite teeth, are recorded with a preferably optical measuring device, and the values generated are saved in a memory. Here, a 3D-measuring camera is used as the measuring device, by which a monochrome 3D-image is generated based on the object to be recorded, the prepared tooth, by applying an opaque, diffusely reflecting layer upon the object and subsequently the object being illuminated with a monochrome light source.

[0002] In a second step, the image is interpreted by the operator, i.e. base lines, cavity edges, equator lines, peaks, etc. must be detected and marked in the image. This occurs largely by the hand of an experienced physician. In a third step the restoration object (inlay, onlay, crown, veneer, etc.) is constructed. This task requires professional CAD work by an operator with a three-dimensional imagination and the capability to perform construction work via a monitor using computer means.

[0003] The quality of the restoration here depends considerably on the capabilities and the training level of the operator. In a fourth step the result of this construction activity is translated into a program for a numerically-controlled cutting/polishing machine. In a fifth step finally the restoration object is produced in the NC-machine from a material block. In the last step the restoration object is integrated in the jaw.

[0004] The image interpretation, being conditional for any successful reconstruction, represents a problem, here. In the currently common method, as already discussed at the outset, the respective surface is first coated with an opaque, diffusely reflecting material and the object is then illuminated with a monochrome light source. The monochrome image yielded of the object under this layer aggravates the identification of the material displayed. For example, it cannot always be detected unambiguously if the displayed part represents a tooth or gums, or if here diseased or healthy material is shown.

[0005] The invention disclosed in claim 1 is based on the objective to improve the 3D-image interpretation.

[0006] It is suggested by the invention, in addition to the monochrome 3D-measuring image, also to record color images and to use them for the image interpretation and restoration by overlapping the color images with the 3D-measuring image, with the very same camera generating both images. The 3D-measuring camera is here modified such that it can also record color images. For this purpose, the following process may be applied:

[0007] The object is not illuminated with monochrome light, but with white light. The camera receives, instead of a black-and-white CCD here a color CCD with an upstream color filter screen, with the upstream provided color filter screen respectively being permeable for the specific color of the pixel used in the CCD and the color of the measuring system (frequently in the IR-range). The camera lens is here color-corrected, i.e. all lenses and prism systems are corrected with regards to color. The supply with light can occur via a light conductor or also via an external light source.

[0008] Alternatively, the measuring object may be dissected during the color recording successively with the characteristic colors red, green, blue, or the light reflected by the object may be divided sequentially into the three colors. For this purpose the camera lens is once more color-corrected (achromatic). The CCD is sensitive over the visible range up to the measuring range. The reflected light is sequentially received by the camera. The three images developing here successively are calculated electronically into color images. The illumination in the three colors can occur by light sources arranged inside or outside the camera, in the latter case requiring a suitable light conductor. It may be advantageous to use three laser diodes emitting different wavelengths; alternatively a rotating color filter may also be provided in front of a conventional light bulb. The black-and-white 3D images and the color images are advantageously displayed simultaneously on a monitor in a superimposed or side-by-side fashion. It is particularly advantageous to display both images on the monitor in a superimposed fashion. This way an optimum of potential interpretations of the image can be yielded, in particular the lines, edges, transitions, etc. can be detected in a considerably better fashion.

[0009] In the following, the invention is described based on exemplary embodiments.

[0010] Fig. 1 shows an embodiment of a conventional measuring camera as disclosed in US-PS 4 575 805 mentioned at the outset. Such a measuring camera, generically marked 1, includes a monochrome light source 2, punctiform if possible, preferably an LED which emits in the infrared range. Upon passing through a condenser 3 the light impinges an oscillating laminar grid 4. The laminar grid 4 is projected via the (upper) hole of a two-aperture plate 5, a lens 6, a head prism 7, and a field lens 8 onto the object to be measured. Using the reverse path, the reflected light reaches a CCD-sensor 10 via the other (lower) hole of the two-aperture plate 5, and a deflection prism 9. The CCD-sensor is here a black-and-white CCD-sensor. In an image electronic 11 and a computer, not shown, outside the camera the image information yielded is calculated into 3D-images.

[0011] There are now two generally different paths to modify the above-described 3D-measuring camera into a color video camera.

[0012] The object is illuminated with white light, instead of monochrome light, and the black-and-white CCD sensor 10 is replaced by a color CCD sensor 10’ with an upstream color filter screen. The lenses and prism systems provided in the camera are corrected chromatically using common optic measures (achromatic). The light source may here, as shown in Fig. 1, be arranged in the camera or also externally in a distant light module.

[0013] As a second path, alternatively it is suggested to illuminate the object not with white light and to record the images with a color-CCD sensor, but to provide an arbitrary, preferably a black-and-white CCD sensor, and to sequentially illuminate the object with at least three colors, and to sequentially dissect the light reflected by the object into the three colors. The advantage of this variant is given, among other things, in a considerably higher resolution of the CCDs (one pixel per light dot, compared to three pixels per light dot in a color CCD).

[0014] The illumination with three different colors can, as described above, be performed by the camera optic via separate light conductors, guided and passed the camera optic, or also with the help of an external light source.

[0015] The three colors may be generated e.g., by three pulsed LEDs or also by three rotating or oscillating color filter disks in front of a common light bulb or arc light.

[0016] An advantageous version of this alternative solution is described in greater detail based on Fig. 2. A light module 12 is arranged outside the camera 1, which is connected via a cable 13 to the camera 1. A

common light source 14 is located in the light module 12, which emits white light. The light is guided via a cable 13, laid in the fiber optic 15 (light conductor), to the camera optic (Fig. 1). (The light source 2 in Fig. 1 is then not present). The light of the three colors can be generated with a filter disk 16 arranged in the light module 12, which is arranged in a rotating fashion between the light source 14 and the light entry into the fiber optic 15. The filter disk 16 may comprise three sectors or segments, which are permeable for three different colors and e.g., are rotated by a pecker 17. The position of the disk can be detected by an angular transmitter 18. In the measuring mode the disk is stationary at one color. In the search mode the disk rotates such that the object is successively illuminated with the three colors. The CCDE sensor 10 in the camera successively records the images. In an image processing electronic 20, which may also include the motor control, these three images are processed into video signals, which can then be frozen in a so-called frame grabber.

[trilingual:]

Claims

1. Process for computer-assisted restoration of teeth, using a 3D measuring camera with which a monochrome 3D image of the object to be recorded is generated, characterized in that, for better image interpretation of the same object, colour video images are generated, displayed on a screen and superimposed on the monochrome 3D image, both recordings being made with one and the same camera.

2. Device for computer-assisted restoration of teeth using a 3D measuring camera with which on the one hand a monochrome 3D image of the object to be recorded is generated, in that a grating is projected onto the possibly surface-coated object to be measured, is recorded at a parallax angle and is further processed to form the monochrome 3D image, characterized in that the 3D measuring camera is also designed for recording colour video images and for superimposing them on the monochrome 3D image, a light source emitting a white light being present and the 3D measuring camera (1) being provided with a colour CCD (10') and with an attached colour filter mask being respectively transparent to the specific colour of the pixel and to the colour of the measuring system.

3. Device for computer-assisted restoration of teeth, having a 3D measuring camera with which on the one hand a monochrome 3D image of the object to be recorded is generated, in that a grating is projected onto the possibly surface-coated object to be measured, is recorded at a parallax angle and is further processed to form the monochrome 3D image, characterized in that the 3D measuring camera is also designed for recording colour video images and for superimposing them on the monochrome 3D image, the 3D measuring camera including any desired, preferably a monochrome CCD sensor (10) and there being means (16) present by which the object can be sequentially illuminated with at least three colours or the light reflected from the object can be sequentially broken up into at least three colours.

4. Device according to Claim 3, characterized in that at least three pulsed LEDs are provided as the light source.

5. Device according to Claim 3, characterized in that a white-light-emitting light source (14) is provided and a rotating or oscillating colour filter disc (16), which is formed in separate segments transparent to at least three different colours, can be brought into the path of rays of the illuminating or reflection light of the said light source.

6. Device according to one of Claims 2 to 5, characterized in that the light source (14) is accommodated in a light module (12) arranged outside the camera (1).

7. Device according to one of the preceding claims, characterized in that there are means present by which the 3D and video images to be brought into a relationship can be adapted in their size and direction of projection.

8. Device according to one of Claims 2 to 7, characterized in that a computer is present by which the image superimposing can be carried out.

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