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(54) **INTRA-ORAL IMAGING SYSTEM**

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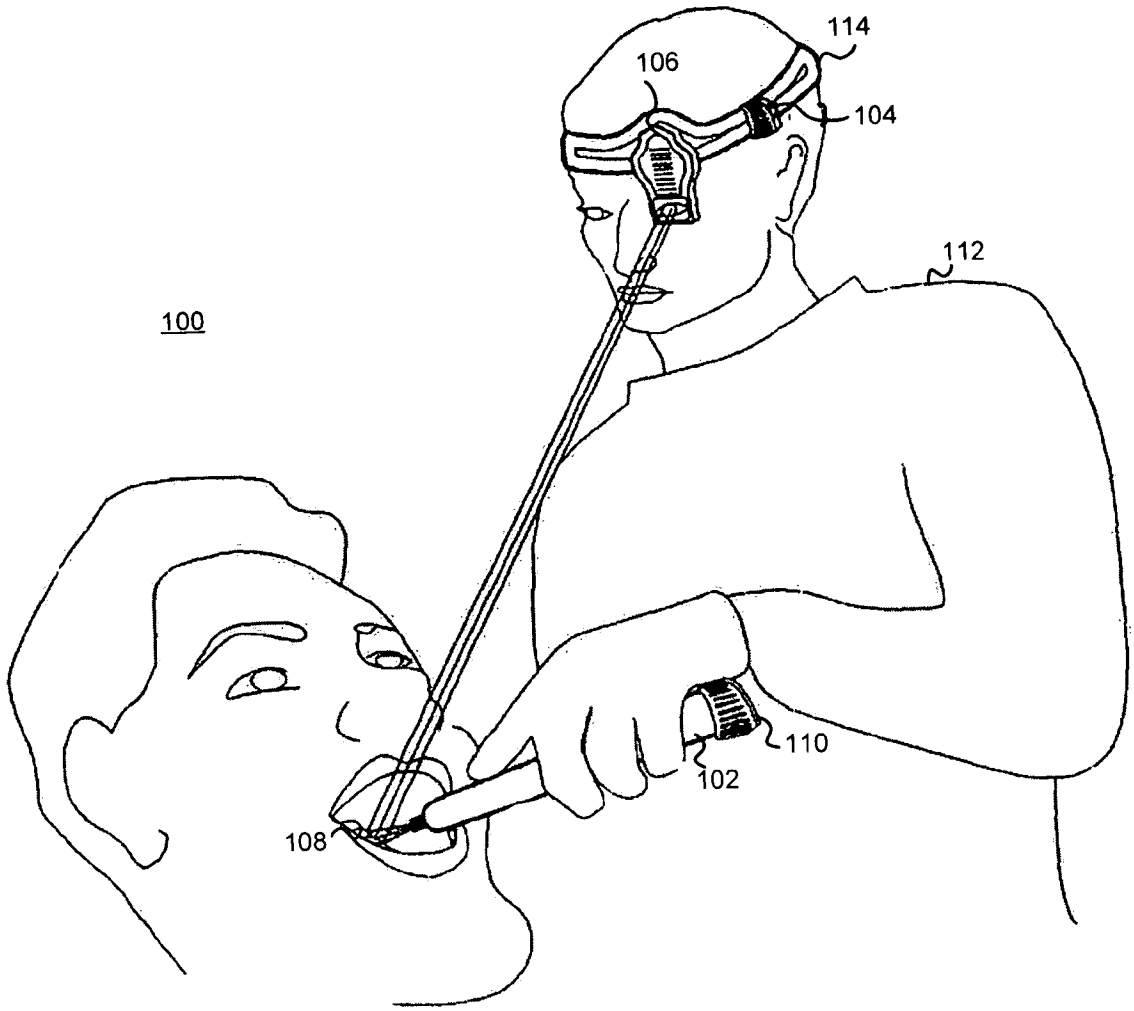
(57) **ABSTRACT**

A digitized image of a tangible object is displayed in an operator's field of view of the object almost simultaneously as the digitized image is being captured. The image is projected onto a screen in an orientation, position and scale corresponding to an orientation and position of the object within the field of view of the operator so as to be perceived as an overlay to the object. The image may be a one-, two, three, or other multi-dimensional representation of the object and may be captured by an imaging system, such as an intra-oral imaging device.



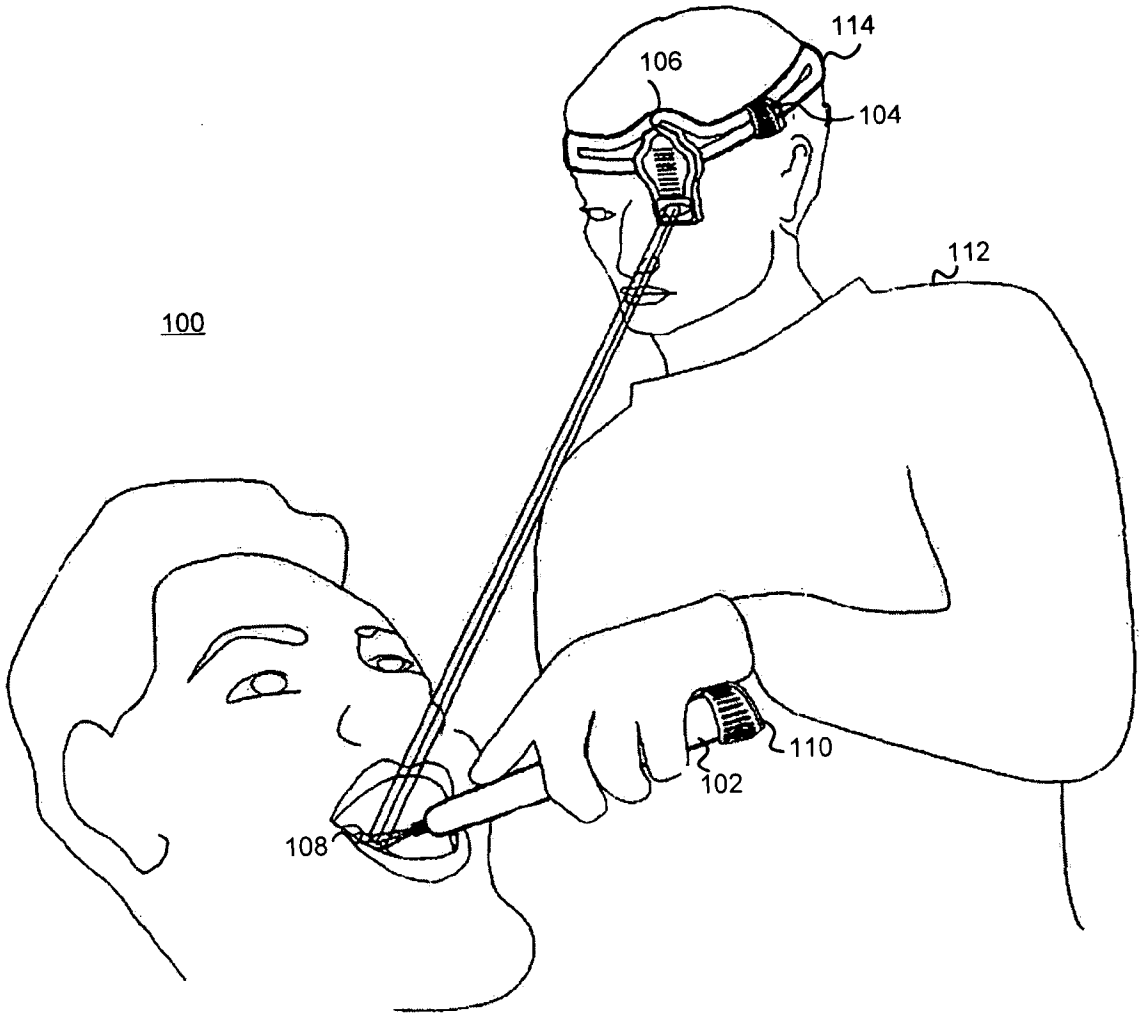


Figure 1

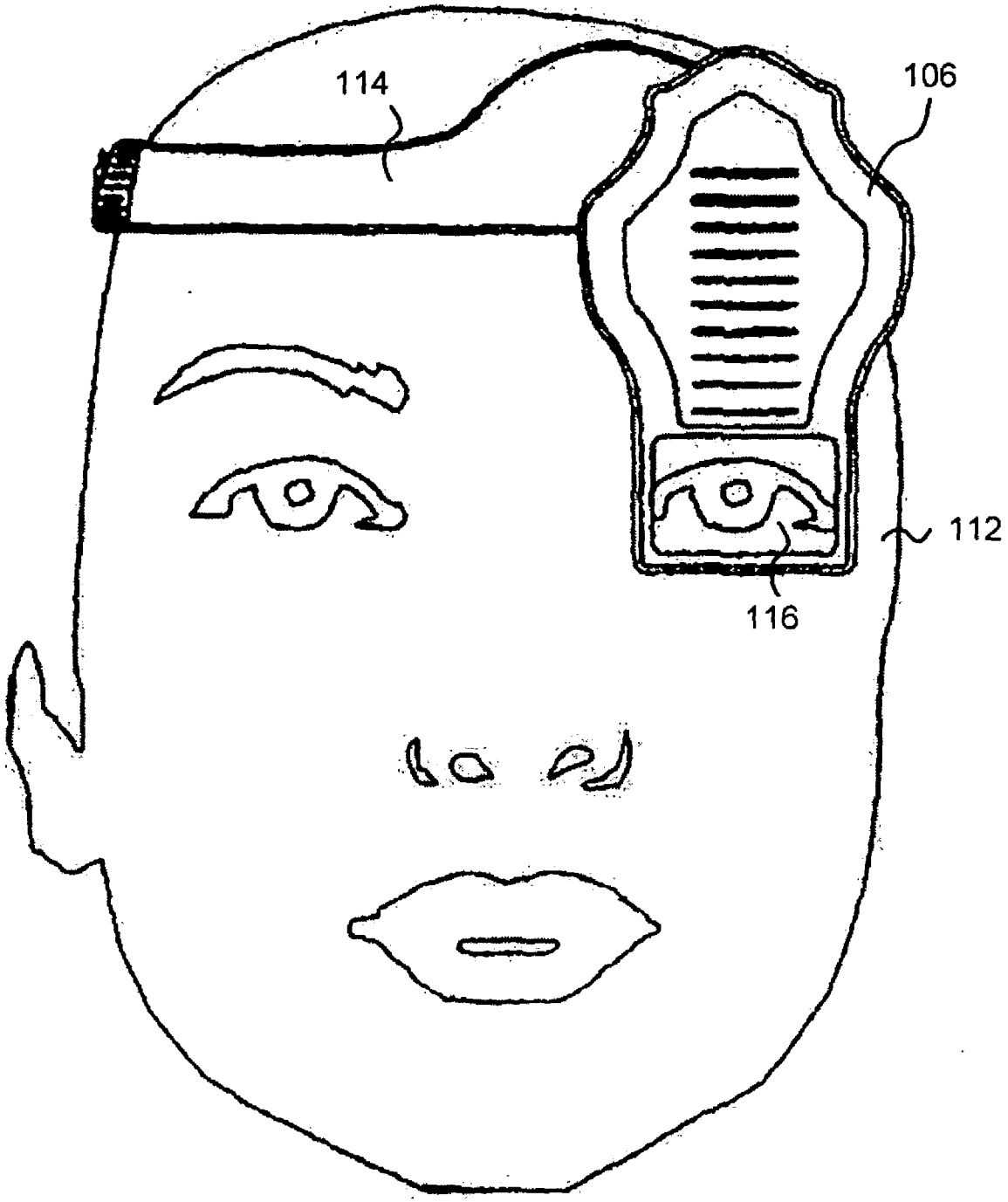


Figure 2

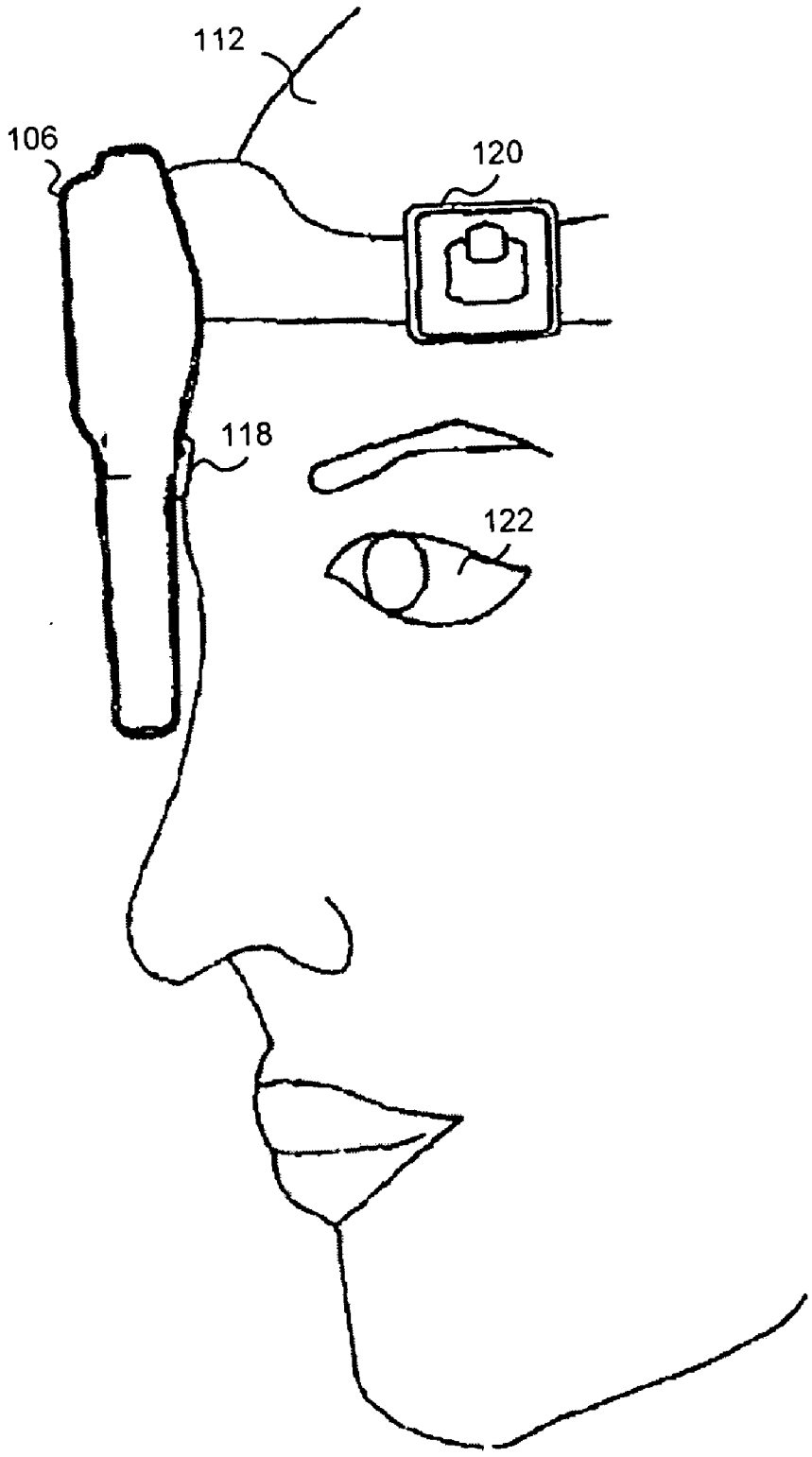


Figure 3

INTRA-ORAL IMAGING SYSTEM

PRIORITY AND CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit under 35 U.S.C. § 119(e) of co-pending provisional application No. 60/466,549 filed on Apr. 30, 2003, for Digitizing/Imaging System with Head-Mounted Display For Dental Applications, which is incorporated in its entirety herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Related Field

[0003] The invention relates to three-dimensional imaging of objects. In particular, the invention relates to displaying a three-dimensional image of an intra-oral (in vivo) dental item that may include dentition, prepared dentition, restorations, impression materials and the like.

[0004] 2. Description of the Related Art

[0005] Existing intra-oral imaging systems may use a Moiré imaging technique. With Moiré imaging, a three-dimensional ("3D") image of a physical object may be generated by scanning the object with white light. The 3D image may be viewed on a display or video monitor. Operators may evaluate the 3D image only through the display, which may require the operator to look away from the object. In addition, there may be little or no feedback as to whether the image is suitable for its intended purpose.

SUMMARY OF THE INVENTION

[0006] An imaging embodiment projects or displays a computer-generated visual image in a field of view of an operator. The systems, methods, apparatuses, and techniques digitize physical objects, such as dental items. The image may be displayed on and viewed through a head-mounted display ("HMD"), which displays computer-generated images that are easily viewed by the operator. The image also may be displayed on a computer monitor, screen, display, or the like.

[0007] A computer-generated image may correspond to an image of a real-world object. The image may be captured with an imaging device, such as an intra-oral imaging system. The intra-oral imaging embodiment projects structured light toward tissue in an oral cavity so that the light is reflected from a surface of that tissue. The tissue may include a tooth, multiple teeth, a preparation, a restoration or other dentition. The intra-oral imaging embodiment detects the reflected white light and generates a dataset related to characteristics of the tissue. The dataset is then processed by a controller to generate a visual image. The controller-generated visual image may be displayed on a screen in the HMD. The image may be displayed at a position and/or orientation corresponding to position and/or orientation of the tissue within the field of view of an operator. The imaging embodiment senses changes in a field of view of an operator, such as by movement of the operator's head, and adjusts the position and/or orientation of the image to correspond with the changes in the field of view of the operator.

[0008] An imaging embodiment may include an imaging device. The imaging device may project light towards or onto a surface of the object so that the light is reflected from the object. The imaging system generates a dataset that represents some or substantially of the surface characteristics of the object. The imaging system may include a tracking sensor that tracks a position of the imaging system relative to the head-mounted display. The tracking sensor may detect an orientation of the imaging system to provide temporal orientation information. The tracking sensor also may detect a position of the imaging device to provide temporal position information. The orientation information may include data related to various angles of the imaging device relative to a predetermined origin in free space. The position information may include data related to a distance or position measurement of the imaging device relative to a predetermined origin in free space. The orientation information may include data for multiple angles, such as three angles, and the position may include measurements along multiple axes, such as three axes. Accordingly, the tracking sensor may provide information for multiple degrees of freedom such as the six-degrees of freedom described above. The dataset generated by the imaging system may also correspond to a two-dimensional or a three dimensional representation of the surfaces of an object.

[0009] The imaging device may manipulate the properties of white light through Moiré or image encoding, laser triangulation, confocal or coherence tomography, or wave front sensing. The coherence tomography imaging may digitize a surface representation of the object that may be visually occluded. For example, an imaging device based on coherence tomography may capture an image of the tooth structure behind soft tissues such as the underlying gum tissue, other soft matter such as tartar, food particles, or any other material.

[0010] A processor may receive the dataset from the imaging device. Based on the information contained in the dataset, the processor may generate signals representative of a visual image of the surface of the object. The processor may generate signals substantially simultaneously as the generation of the dataset by the imaging system. The processor also may generate signals in response to receiving the dataset or as the dataset is received. The processor may be coupled to the imaging system through a link that may include wires, cables, via radio frequency, infra-red, microwave communications and/or some other technology that does not require physical connection between the processor and imaging system. The processor may be portable and may be worn by the operator.

[0011] The HMD may be fitted or otherwise coupled to the head of an operator. The HMD receives the signals from the processor. Based on the signals received from the processor, the HMD may project the image onto a screen positioned in the field of view of an operator. The HMD may project the image to be seen by one or both eyes of the operator. The HMD may project a single image or a stereoscopic image.

[0012] The HMD may include a HMD position sensor. The position sensor may track the HMD's position relative to a predetermined origin or reference point. The position sensor also may detect an orientation of the HMD to provide HMD orientation information as a function of time. The

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