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(54) METHOD AND APPARATUS FOR COMPUTING A COMPUTER GRAPHICS IMAGE OF A TEXTURED SURFACE

VERFAHREN UND GERÄT ZUM BERECHNEN EINES GRAPHISCHEN BILDES EINER TEXTURIERTEN OBERFLÄCHE

PROCEDE ET DISPOSITIF SERVANT A CALCULER UNE IMAGE INFOGRAPHIQUE D'UNE SURFACE TEXTUREE

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WO-A-98/22911

- **"SIMPLE WAY TO GENERATE UNUSUAL SPECULAR REFLECTIONS" IBM TECHNICAL DISCLOSURE BULLETIN,US,IBM CORP. NEW YORK, vol. 33, no. 3A, 1 August 1990 (1990-08-01), pages 14-15, XP000123835 ISSN: 0018-8689**

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Description

[0001] The invention relates to a method of computing a pixel value for a pixel in a texture mapped computer graphics image.

[0002] Texture mapping and bump mapping are mapping techniques for increasing the realism of computer graphics images. These mapping techniques are used to create color patterns and visual effects of unevenness in an image part that shows a surface, which is modeled as a flat polygon in three-dimensional space. These mapping techniques use an approximation to compute the image. A two-dimensional map (the texture map or the bump map) is provided, for example as an array of values stored in computer memory. Each location on the surface is assigned to a location in the map. When the pixel value of a pixel in the image is computed, one computes which location on the surface is visible in the pixel and determines the pixel value from the value stored in the two dimensional map for the location in the map which is assigned to that location on the surface. In case of a texture map, a color value (e.g. RGB combination) from the map is used to compute a surface color. In case of a bump map, a local surface orientation is determined from the bump map and this orientation is used to compute visible reflections from the surface.

[0003] Texture mapping and bump mapping increase the sense of realism that is experienced when viewing the image. A further increase can be realized by including parallax effects. This is realized for example in PCT patent application No. WO 98/92911 (by the same inventor) which creates a parallax effects by combining information from two texture maps for one surface, where the two texture maps are offset to one another in a direction normal to the surface. In WO 98/22911 it is proposed to apply two texture maps where one texture map (A) is shifted in a view-dependent direction and view-dependent amount with respect to the other texture map (B). In combination with that, the other texture map (B) is made transparent in some places to show the one texture map (A) (e.g. a window in a brick wall lies somewhat deeper, so the brick texture (B) has a hole in the place where the window texture (A) should come. Thanks to shifting the texture map (A), the window appears to lay deeper due to parallax.) This gives a pseudo-3D effect in a much cheaper way than having to model the actual 3-D geometry.

[0004] It is an object of the invention to provide a method and apparatus for generating computer graphics images with additional realism.

[0005] The method according to the invention is set forth in Claim 1. According to the invention, the surface texture in a pixel is determined from the content of the texture map at a texture map location. The texture map location is determined by applying an offset to a location in the texture map that is assigned to the surface location which is visible in the pixel. The offset is determined from a surface height for the surface location, as determined from a displacement map. Thus, a parallax in the texture is simulated. The parallax corresponds to unevenness of the surface as described by the displacement map.

[0006] The parallax also depends on the current viewing direction relative to the local normal vector. So in order to compute the offset, both the surface height and the viewing parameters are taken into account.

[0007] Preferably, the computation of parallax from the displacement map is combined with computation of angular dependence of reflections (specular and/or diffuse reflections) and/or shadows cast from the unevenness described by the displacement map. The computation of parallax effect will automatically account for some effects of occlusion: hiding of certain surface details by other surface details.

[0008] The invention also relates to an apparatus with computer graphics capability that is structured and/or programmed to perform the method according to the invention.

[0009] These and other advantageous aspects of the invention will be described by way of non-limitative example using the following figures, wherein

Fig. 1 shows a computer graphic apparatus
Fig. 2 shows an example of a two-dimensional cross-section of a three dimensional space
Fig. 3 illustrates the parallax effect caused by height variations.

[0010] Figure 1 shows a computer graphics apparatus. The apparatus contains a pixel control unit 10 coupled to a model memory 11. An output of the pixel control unit 10 is coupled to an offset generator 12 and a displacement map memory 13. The displacement map memory 13 is coupled to the offset generator 12. The offset generator 12 has an output coupled to a texture memory 15 and a pixel value generator 14. The texture memory 15 has an output coupled to the pixel value generator 14. The pixel generator has an output to a display unit 16, which also has an input to the pixel control unit 10.

[0011] In operation, the pixel control unit 10 visits a number of pixels. By way of example, the pixel control unit 10 successively visits spatially successive pixels along a scan line of an image. The pixel control unit 10 signals the location of the pixel being visited to the display unit 16, e.g. by means of a pixel clock that signals advance along the scan line.

[0012] Figure 2 shows an example of a two-dimensional cross-section of a three dimensional space that contains an object described by model. The cross-section shows two surfaces 20, 22 in cross-section. In addition, a viewpoint 23 is shown and a line of sight 24 from the viewpoint 23 to one of the surfaces 20. The line of sight 24 intersects this surface 20 at a surface location 25.

[0013] A displacement map is provided at least for the first surface 20. The displacement map defines a height profile 26 for this surface 20. The height profile 26 corresponds for example to displacement of each surface location by a location dependent amount along the normal of the surface at that surface location.

[0014] The location dependent amount is specified for example by means of a function of two-dimensional coordinates. Values of this function for different coordinates may be stored as an array of values in the displacement map memory 13. The model specifies the function that is to be used for each surface 20, 22. The model also specifies a relation between on one hand two dimensional coordinates are used as arguments for the function and on the other hand surface coordinates of locations on the surface 20, 22. Thus, a function value is assigned to each location on the surface.

[0015] The pixel control unit 10 determines which modeled surface 20 is visible at a visited pixel. The pixel control unit 10 also determines the two-dimensional coordinates of the surface location 25 that is visible at the pixel. From this information, the pixel control unit 10 determines an address to retrieve the appropriate displacement map value from the displacement map memory 13. The pixel control unit 10 thereupon accesses the displacement map memory 13, to obtain a displacement map value for the visible surface 20 at the coordinates of the surface location 25. The pixel control unit 10 also determines the normal to the surface 20 at this surface location 25. The pixel control unit 10 signals an indication of the coordinates and the normal to the offset generator 14.

[0016] The offset generator 14 receives an indication of the visible surface 20 and the surface coordinates of the surface location. The offset generator 14 applies an offset to the surface coordinates.

[0017] The resulting surface coordinates and an indication of the modeled surface 20 that is visible are used to address the texture map memory 15. The texture map memory 15 stores texture map values that describe for example a color pattern of location dependent light reflected from the surface (optionally the texture map is also normal vector orientation dependent; in this case the normal vector is also used to address texture map memory 15). In response to addressing from the offset generator 12 the texture map memory 15 provides a texture value for the location 25 that is visible for at visited pixel.

[0018] The pixel value generator 14 uses the texture map value and the normal to the surface to compute the pixel value of the visited pixel. This pixel value is passed to the display unit 16, for display on a display screen at a pixel location defined by the visited pixel. Preferably, the display unit 16 stores the pixel value in a frame buffer (not shown) at a location determined by the coordinates of the visited pixel, for later display on a display screen.

[0019] As mentioned, the offset generator 14 applies an offset to the surface coordinates. The offset accounts for a parallax effect corresponding to height variations of the surface 20 as defined by the displacement map.

[0020] Figure 3 illustrates the parallax effect caused by height variations. A surface 30 is shown in cross-section, with a height profile 32. A line of sight 34 intersects the surface 30 at a first surface location 35. It intersects the height profile 32 at a profile location 36. The profile location 36 corresponds to a second surface location 37, obtained by displacing the profile location 36 along the normal to the surface. Without parallax, the texture for the first surface location 35 would be visible along the line of sight 34. Due to parallax, the texture for the second surface location 37 will be visible along the line of sight 34. That is, the surface coordinate for which a texture value is obtained is offset from the surface of the coordinates of the first location 35 by a vector D, where

$$D = h\ Pe$$

[0021] Here "h" is the displacement along the normal defined by the displacement map for the second location 37, and Pe is a projection onto the surface 30 of a normal vector "e" in the direction of the line of sight 34. In general, the offset will be small compared with the variation of the displacement "h" along the surface 30 and therefore a reasonable approximation of the parallax can be obtained by taking the displacement h for the first surface location 35 instead of that for the second surface location 37.

[0022] In any case, the offset does not need to be computed with extreme precision in order to create a convincing visual impression of an uneven surface. A convincing visual impression is created by this approximation, or similar approximations, because the approximation normally provides a parallax in the right direction and with an amplitude that is responsive to height variation.

[0023] The offset generator 14 applies offsets to the surface coordinates of visited pixels. The offset generator 14 determines the offset dependent on the displacement map height value h that is obtained35 from the displacement map memory 13 for the first surface location 35 where the line of sight 34 from the visited pixel intersects the flat modeled surface 30. The offset generator 14 adds this offset to received coordinates of the first surface location 35. The offset generator 14 applies the resulting coordinates as an address to texture memory 15. Pixel value generator 16 uses the addressed content of texture memory 15 to generate a pixel value. Thus, the pixel value corresponds to a texture that is locally offset by the offset computed by the offset generator 14.

[0024] Preferably, the pixel control unit 10 computes the normal to the surface by interpolation of values of the normal for the corners of the surface, as is known for shading calculations such as Phong shading, so that the normal may vary over the surface. The interpolated normal that is used for computing reflected light intensity preferably is also used to compute the offset in the offset generator 14. Thus, there will be no visible jumps in parallax at the junctions between different surfaces that are used to model objects.

[0025] Of course, the implementation described above is merely an example of how the invention can be applied. Many variations are conceivable, such as implementation of the different units 10, 12, 14 in a suitably programmed computer, and/or implementation of one or more of the different memories 11, 13, 15 as different regions in a larger memory. Other variations include computing displacement map and/or texture values from a function instead of obtaining them from memory. Similarly, instead of using flat surfaces to model the shape of an object one may use curved surfaces, such as Bezier triangles or implicit surfaces as a model to compute the points of intersection, surface coordinates etc.

[0026] By accounting for parallax, some effect of occlusion (disappearance of some surface detail behind a different surface part) is automatically accounted for. If desired, a further computation of occlusion may be included to increase the experienced realism of the image.

[0027] Preferably, the application of an offset to suggest parallax is combined with computations to account for effects of unevenness such as the casting of shadows and/or surface orientation dependent reflection (preferably both diffuse and specular reflection). To a considerable extent, these computations use the same information about the surface (surface coordinates, normals, displacement maps) as the computation of parallax. Therefore, computation of parallax can be added to these computations without much computational overhead. When combined in a consistent way (i.e. using the same displacement map), the combination of the effects increases the experienced realism of surfaces.

Claims

1. A method of computing a pixel value for a pixel in a texture mapped computer graphics image, the method comprising:

   - defining a surface (20, 30) in a three dimensional space, to which a texture is to be applied;
   - defining a texture map having texture values and a corresponding displacement map having displacement map values (32), the displacement map representing a height profile for said surface, the displacement map values being displacements of each surface location by a location dependent amount along the normal of the surface at that surface location;
   - computing surface coordinates for a location of intersection (35) of the surface (30) with a line of sight (34) for the pixel;
   - computing a surface coordinate offset vector that represents a change in the surface coordinates of said intersection (35), the surface coordinate offset vector being dependent on the displacement map value at the location of said intersection (35);
   - modifying said surface coordinate of said location of intersection (35) by said offset vector, and
   - computing a pixel value for the pixel in the computer graphics image from a texture value defined at said modified location of intersection (37), thereby simulating parallax effects.

2. A method according to claim 1, also comprising computation of angular dependence of reflected light intensity from the surface (30), dependent on a surface orientation modified in correspondence with said displacement map values.

3. A method according to claim 2, wherein said displacement map value defined for said surface coordinates offset by said offset vector is used for computing angular dependence of the reflected light intensity.

4. A method according to claim 2, also comprising computation of shadows cast from unevenness of the surface (30) in correspondence with said displacement map values.

5. A texture mapped computer graphics image generator comprising:

   - a surface model input for receiving model that defines a surface (30) in a three dimensional space, to which a texture is to be applied;
   - a texture map memory for storing a texture map that defines texture values and a corresponding displacement map having displacement map values (32), the displacement map representing a height profile for said surface, the displacement map values being displacements of each surface location by a location dependent amount along the normal of the surface at that surface location;
   - a processing circuit arranged for:
   - computing surface coordinates for a location of intersection (35) of the surface (30) with a line of sight (34) for the pixel;
   - computing a surface coordinate offset vector that represents a change in the surface coordinates of said intersection (35), the surface coordinate offset vector being dependent on the displacement map value at the location of said intersection (35);
   - modifying said surface coordinate of said location of intersection (35) by said offset vector; and
   - computing a pixel value for the pixel in the computer graphics image from a texture value defined at said modified location of intersection (37), thereby simulating parallax effects.

6. A generator according to claim 5, the processing circuit being arranged to determine an angular dependence of reflected light intensity from the surface (30),

dependent on a surface orientation modified in correspondence with said displacement map values.

7. A generator according to claim 6, wherein said displacement map value defined for said surface coordinates offset by said offset vector is used for computing angular dependence of the reflected light intensity.

8. A generator according to claim 6, the processing circuit being arranged to compute an effect of shadows cast from unevenness of the surface in correspondence with said displacement map values.

Patentansprüche

1. Verfahren zum Berechnen eines Pixelwerts für ein Pixel in einem Computergrafikbild mit Texturabbildung, wobei das Verfahren umfasst:

   - das Definieren einer Oberfläche (20, 30) in einem dreidimensionalen Raum, auf welche eine Textur angewandt werden soll;
   - das Definieren einer Texture Map, die Texturwerte aufweist, und einer entsprechenden Displacement Map, die Displacement Map-Werte (32) aufweist, wobei die Displacement Map ein Höhenprofil für diese Oberfläche darstellt, wobei die Displacement Map-Werte Verschiebungen jeder Oberflächenposition um eine positionsabhängige Menge entlang der Normalen der Oberfläche an dieser Oberflächenposition sind;
   - das Berechnen von Oberflächenkoordinaten für eine Schnittpunktposition (35) der Oberfläche (30) mit einer Sichtlinie (34) für das Pixel;
   - das Berechnen eines Oberflächenkoordinatenversatzvektors, der eine Änderung in den Oberflächenkoordinaten des Schnittpunkts (35) darstellt, wobei der Oberflächenkoordinatenversatzvektor vom Displacement Map-Wert an der Position des Schnittpunkts (35) abhängig ist;
   - das Modifizieren der Oberflächenkoordinate der Schnittpunktposition (35) um diesen Versatzvektor; und
   - das Berechnen eines Pixelwerts für das Pixel im Computergrafikbild anhand eines Texturwerts, der an dieser modifizierten Schnittpunktposition (37) definiert ist, wodurch Parallaxeeffekte simuliert werden.

2. Verfahren nach Anspruch 1, auch umfassend das Berechnen der Winkelabhängigkeit der von der Oberfläche (30) reflektierten Lichtstärke, die abhängig ist von einer Oberflächenorientierung, die den Displacement Map-Werten entsprechend modifiziert wird.

3. Verfahren nach Anspruch 2, wobei der Displacement Map-Wert, der für die Oberflächenkoordinaten definiert ist, um den Versatzvektor versetzt ist, der verwendet wird, um die Winkelabhängigkeit der reflektierten Lichtstärke zu berechnen.

4. Verfahren nach Anspruch 2, auch umfassend das Berechnen von Schatten, die von Unebenheiten der Oberfläche (30) den Displacement Map-Werten entsprechend geworfen werden.

5. Computergrafikbildgenerator mit Texturabbildung, umfassend:

   - einen Oberflächenmodelleingang zum Empfangen des Modells, das eine Oberfläche (30) in einem dreidimensionalen Raum definiert, auf welche eine Textur anzuwenden ist;
   - einen Texture Map-Speicher zum Speichern einer Texture Map, die Texturwerte definiert, und einer entsprechenden Displacement Map, die Displacement Map-Werte (32) aufweist, wobei die Displacement Map ein Höhenprofil für diese Oberfläche darstellt, wobei die Displacement Map-Werte Verschiebungen jeder Oberflächenposition um eine positionsabhängige Menge entlang der Normalen der Oberfläche an dieser Oberflächenposition sind;
   - eine Verarbeitungsschaltung, angeordnet zum:
   - Berechnen der Oberflächenkoordinaten für eine Schnittpunktposition (35) der Oberfläche (30) mit einer Sichtlinie (34) für das Pixel;
   - Berechnen eines Oberflächenkoordinatenversatzvektors, der eine Änderung in den Oberflächenkoordinaten dieses Schnittpunkts (35) darstellt, wobei der Oberflächenkoordinatenversatzvektor vom Displacement Map-Wert an der Position des Schnittpunkts (35) abhängig ist;
   - Modifizierens der Oberflächenkoordinate und der Schnittpunktposition (35) um diesen Versatzvektor; und
   - Berechnens eines Pixelwerts für das Pixel im Computergrafikbild anhand eines Texturwerts, der an dieser modifizierten Schnittpunktposition (37) definiert ist, wodurch Parallaxeeffekte simuliert werden.

6. Generator nach Anspruch 5, wobei die Verarbeitungsschaltung angeordnet ist, um eine Winkelabhängigkeit der von der Oberfläche (30) reflektierten Lichtstärke zu bestimmen, abhängig von einer Oberflächenorientierung, die den Displacement Map-Werten entsprechend modifiziert wurde.

7. Generator nach Anspruch 6, wobei der Displacement Map-Wert, der für die Oberflächenkoordinaten definiert ist, die um diesen Versatzvektor versetzt

wurden, verwendet wird, um die Winkelabhängigkeit der reflektierten Lichtstärke zu berechnen.

8. Generator nach Anspruch 6, wobei die Verarbeitungsschaltung angeordnet ist, um einen Effekt von Schatten zu berechnen, die von Unebenheiten der Oberfläche den Displacement Map-Werten entsprechend geworfen werden.

Revendications

1. Procédé pour calculer une valeur de pixel pour un pixel dans une image infographique de projection de texture, le procédé comprenant:

- la définition d'une surface (20, 30) dans un espace tridimensionnel sur laquelle une texture doit être appliquée;
- la définition d'une projection de texture ayant des valeurs de texture et une carte de déplacement correspondante ayant des valeurs de carte de déplacement (32), la carte de déplacement représentant un profil vertical pour ladite surface, les valeurs de carte de déplacement étant des déplacements de chaque emplacement de surface par une quantité étant dépendante de l'emplacement le long de la normale de la surface à cet emplacement de surface;
- le calcul de coordonnées de surface pour un emplacement d'intersection (35) de la surface (30) avec une ligne de visée (34) pour le pixel;
- le calcul d'un vecteur de décalage de la coordonnée de surface qui représente un changement des coordonnées de surface de ladite intersection (35), le vecteur de décalage de la coordonnée de surface étant dépendant de la valeur de carte de déplacement à l'emplacement de ladite intersection (35);
- la modification de ladite coordonnée de surface dudit emplacement d'intersection (35) par ledit vecteur de décalage; et
- le calcul d'une valeur de pixel pour le pixel dans l'image infographique à partir d'une valeur de texture qui est définie audit emplacement d'intersection (37), de ce fait simulant des effets de parallaxe.

2. Procédé selon la revendication 1, comprenant également le calcul d'une dépendance angulaire de l'intensité de la lumière qui est réfléchie à partir de la surface (30) dépendamment d'une orientation de surface qui est modifiée en rapport avec lesdites valeurs de carte de déplacement.

3. Procédé selon la revendication 2, dans lequel ladite valeur de carte de déplacement qui est définie pour ledit décalage de coordonnées de surface par ledit vecteur de décalage est utilisée pour calculer la dépendance angulaire de l'intensité de la lumière réfléchie.

4. Procédé selon la revendication 2, comprenant également le calcul d'une projection d'ombres en provenance de l'inégalité de la surface (30) en rapport avec lesdites valeurs de carte de déplacement.

5. Générateur d'image infographique de projection de texture comprenant:

- une entrée du modèle de surface pour recevoir un modèle qui définit une surface (30) dans un espace tridimensionnel sur laquelle une texture doit être appliquée;
- une mémoire de projection de texture pour stocker une projection de texture qui définit des valeurs de texture et une carte de déplacement correspondante ayant des valeurs de carte de déplacement (32), la carte de déplacement représentant un profil vertical pour ladite surface, les valeurs de carte de déplacement étant des déplacements de chaque emplacement de surface par une quantité étant dépendante de l'emplacement le long de la normale de la surface à cet emplacement de surface;
- un circuit de traitement qui est agencé pour:
- calculer des coordonnées de surface pour un emplacement d'intersection (35) de la surface (30) avec une ligne de visée (34) pour le pixel;
- calculer un vecteur de décalage de la coordonnée de surface qui représente un changement des coordonnées de surface de ladite intersection (35), le vecteur de décalage de la coordonnée de surface étant dépendant de la valeur de carte de déplacement à l'emplacement de ladite intersection (35);
- modifier ladite coordonnée de surface dudit emplacement d'intersection (35) par ledit vecteur de décalage; et
- calculer une valeur de pixel pour le pixel dans l'image infographique à partir d'une valeur de texture qui est définie audit emplacement d'intersection (37), de ce fait simulant des effets de parallaxe.

6. Générateur selon la revendication 5, le circuit de traitement étant agencé de manière à déterminer une dépendance angulaire de l'intensité de la lumière qui est réfléchie à partir de la surface (30) dépendamment d'une orientation de surface qui est modifiée en rapport avec lesdites valeurs de carte de déplacement.

7. Générateur selon la revendication 6, dans lequel ladite valeur de carte de déplacement qui est définie pour ledit décalage de coordonnées de surface par ledit vecteur de décalage est utilisée pour calculer la dépendance angulaire de l'intensité de la lumière réfléchie.

8. Générateur selon la revendication 6, le circuit de traitement étant agencé de manière à calculer un effet de projection d'ombres à partir d'une inégalité de la surface en rapport avec lesdites valeurs de carte de déplacement.

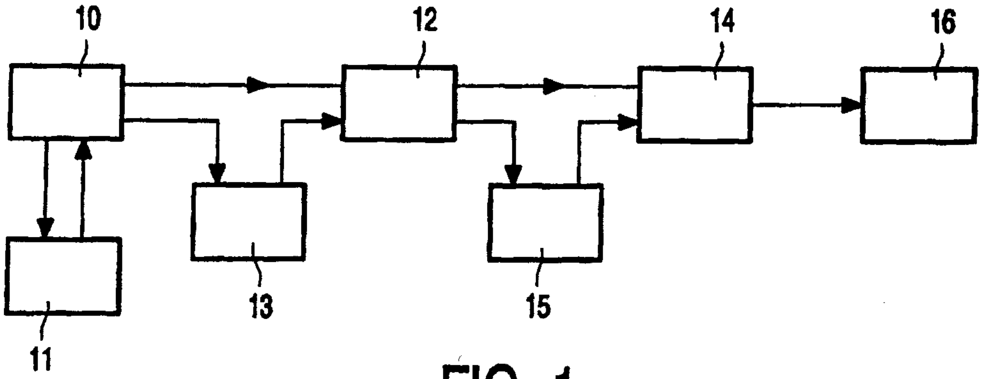

FIG. 1

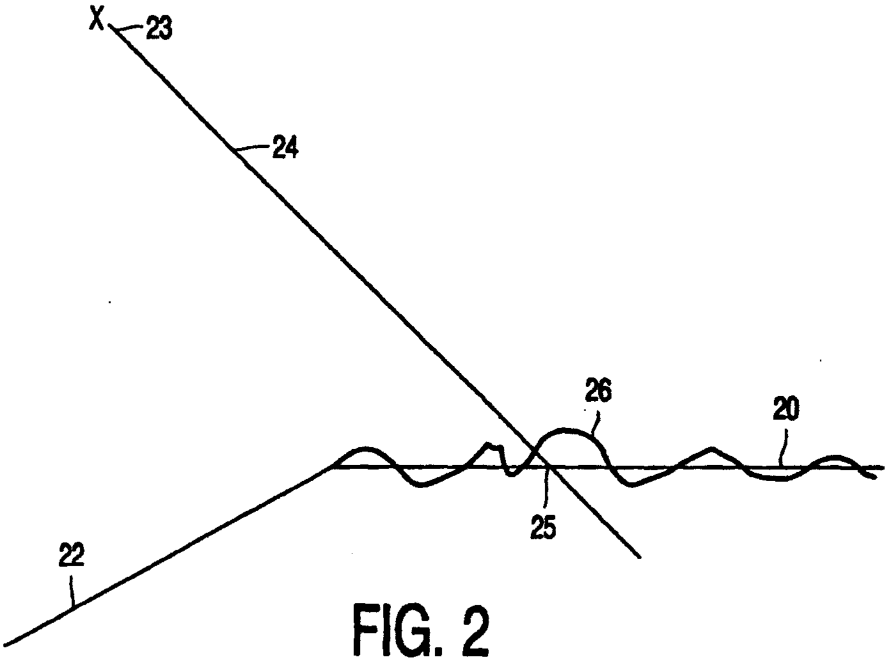

FIG. 2

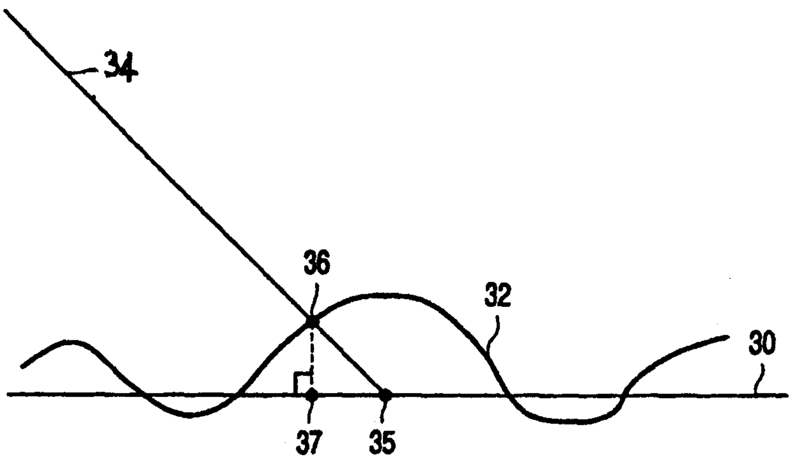

FIG. 3