Apple Inc. (Petitioner)
v.
ImmerVision, Inc. (Patent Owner)

Petitioner's Demonstratives

Case No. IPR2023-00471
U.S. Patent No. 6,844,990

Before Hon. John D. Hamann, Steven M. Amundson, Stephen E. Belisle
Administrative Patent Judges

FISH.

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

APPLE 1028
Apple v. Immervision
IPR2023-00471

Table of Contents

1. The Baker-Shiota Combination Renders Obvious Claim 27 of the ’990 Patent	3
1A: ’990’s Description Relating to “correcting the non-linearity of the initial image … using at least the non-linear distribution function and a size L of the obtained image”	9
1B: Baker-Shiota Renders Obvious “correcting the non-linearity of the initial image … using … a size L of the obtained image” similar to the ’990 Patent’s Description of This Feature	16
2. Appendix 1 - Rebuttals to Patent Owner’s Arguments	32
3. Appendix 2 - Overview of the '990 Patent	41
4. Appendix 3 - Overview of the Baker-Shiota Combination	45

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Issue 1

The Baker-Shiota Combination Renders Obvious Claim 27 of the ’990 Patent

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’990 Patent: Challenged Indep. Claim 27

27. *A method for displaying a digital panoramic image, the method comprising:*

obtaining a digital panoramic image by projecting a panorama onto an image sensor using a panoramic objective lens, the panoramic objective lens having an image point distribution function that is not linear relative to a field angle of object points of the panorama, the distribution function having a maximum divergence of at least +/−10% compared to a linear distribution function, such that the panoramic image obtained has at least one substantially expanded zone and at least one substantially compressed zone; and

displaying the obtained panoramic image by correcting the non-linearity of the initial image, performed by retrieving image points on the obtained image in a coordinate system of center O' using at least the non-linear distribution function and a size L of the obtained image.

The Purported Invention of the '990 Patent

Therefore, the present invention is based on the premise that a panoramic image has some zones that are not very useful and that can tolerate a reasonable definition to the benefit of other zones of the image.

On the basis of this premise, the idea of the present invention is to produce panoramic photographs by means of a panoramic objective lens that is not linear, which expands certain zones of the image and compresses other zones of the image. The technical effect obtained is that the expanded zones of the image cover a number of pixels of the image sensor that is higher than if they were not expanded, and thus benefit from a better definition. By choosing an objective lens that expands the most useful zones of an image (which depend on the intended application), the definition is excellent in these zones and the definition is mediocre in the zones of lesser importance.

'990 Patent's Specification

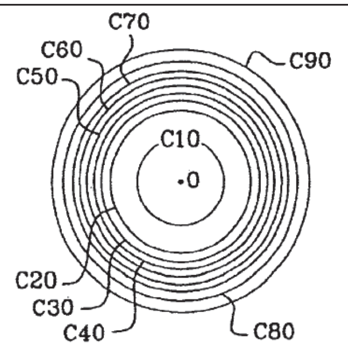

Fig. 7A

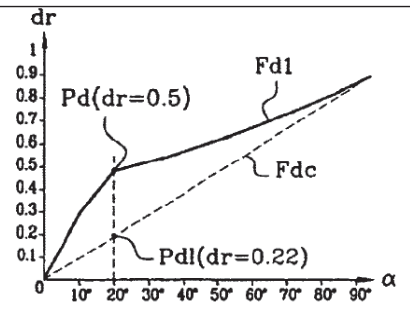

Fig. 7B

APPLE-1001 ('990 Pat), 3:62-4:21, FIGS. 7A-7B; Petition, 8-11

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The Purported Invention of the '990 Patent

'990 Patent's Specification

Second Embodiment of the Correction Method

The second embodiment of the correction method according to the present invention is shown in FIG. **13**. Schematically, this method involves projecting the image points of an image sector corresponding to a display window DW onto the image disk ID**1** of the initial image Img**1**. This method does not require calculating a corrected image disk, contrary to the previous embodiment.

The image points of the display window DW are referenced E(i,j) in the coordinate system of the display window, expressed in line coordinates i and in column coordinates j. The points E(i,j) are first projected onto a sphere portion HS of center O and of axes OX, OY, OZ, to obtain image points P(px, py, pz) belonging to the sphere portion. This sphere portion covers a solid angle that corresponds to the aperture of the objective lens used. The example considered until now was of a panoramic objective lens having an aperture of 180° and the sphere portion HS considered here is therefore a hemisphere. The image points P thus determined are then projected onto the image disk Img1 by means of the non-linear distribution function Fd according to the present invention, which first requires calculating the field angle α of the points P in relation to the center O of the hemisphere.

APPLE-1001, 12:59-14:35; Petition, 11-12

As it will be clear to those skilled in the art, the correction of the non-linearity of the image disk is implicit here since the image points p(pu, pv) corresponding to the image points E(i, j) of the display window DW are "retrieved" from the image disk ID**1**, by means of the function Fd.

Algorithm 2

```
1/ For i=-Imax/2 to i=Imax/2 do [by increments of 1]
2/     For j=-Jmax/2 to j=Jmax/2 do [by increments of 1]
[calculation of the Cartesian coordinates Ex, Ey, Ez
of the point E of the display window in the system OXYZ]
3/       Ey = j*cos(φ0) - Zoom*sin(φ0)
4/       Ez = Zoom*cos(φ0) + j*sin(φ0)
5/       aux1 = Ez
6/       Ez = Ez*cos(θ0) - i*sin(θ0)
7/       Ex = i*cos(θ0) + aux1*sin(θ0)
[calculation of the coordinates of the point P corresponding to the point E]
8/       aux2 = R/√(Ex*Ex + Ey*Ey + Ez*Ez)
9/       Px = Ex*aux2
10/      Py = Ey*aux2
11/      Pz = Ez*aux2
[calculation of the coordinates of the point p corresponding
to the point P, in the coordinate system
(O'UV), by means of the function Fd]
12/      X = Px/R
13/      Y = Py/R
14/      r = √(X*X + Y*Y)
15/      α = arcsine(r)
16/      U = X/r
17/      V = Y/r
18/      pu = L*U*Fd(α)
19/      pv = L*V*Fd(α)
20/      Screen_Pixel[i,j] = Image_Pixel[pu,pv]
21/    end for
22/  end for
```

Patent Owner's Self-Initiated Reexamination

F. Baker and Shiota

Baker teaches a camera with a lens for capturing a hemispheric scene, emphasizing the periphery of the image. A person of ordinary skill in the art would recognize the need to correct the image captured by Baker. Shiota, in the same field of endeavor, teaches a method of transforming a captured image into a plane image for display using the non-linear distribution function. Thus, one of ordinary skill in the art would have had reason to consult Shiota for a method of de-warping the image captured by the panoramic lens of Baker for presentation to a user.

'990 Patent's Reexamination

Claim 27 recites that the non-linearity of the initial image is corrected by retrieving image points on the obtained image in a coordinate system of center O' using at least the non-linear distribution function and a size L of the obtained image. For example, the initial image may be in the form of an image disk having a size L, which may be provided in the number of pixels. Image points p (pu, pv) corresponding to image points E(i, j) of, for example, a display window, can be obtained using equations that multiply, among other things, the size of the image disk L with the non-linear distribution function at an angle □(*e.g.*, pu = L*U*Fd(□) and pv = L*V*Fd(□)). Claim 32 contains a similar recitation.

The references all fail to teach or suggest this feature of claims 27 or 32. As described above with respect to claim 10, Nagaoka, Baker, and Fisher do not describe any specific method for correcting the image. As for Shiota, the second projection points p_1 and q_1 are obtained using a coefficient k_2, which is equal to the distribution function divided by a distance r from the origin of the image disk to a point Q on the image disk. The coefficient k_2 is then multiplied by corresponding coordinates X_2, Y_2 on a hemisphere. (Shiota at Fig. 1; paras. [0033]-[0041]). The size of the image disk is not utilized to correct the image.

APPLE-1011 (Reexam File History), 249-251, 234; Petition, 13-14, 21, 24-25, 47-49, 77-79

’990 Patent: Challenged Indep. Claim 27

27. A method for displaying a digital panoramic image, the method comprising:

obtaining a digital panoramic image by projecting a panorama onto an image sensor using a panoramic objective lens, the panoramic objective lens having an image point distribution function that is not linear relative to a field angle of object points of the panorama, the distribution function having a maximum divergence of at least +/−10% compared to a linear distribution function, such that the panoramic image obtained has at least one substantially expanded zone and at least one substantially compressed zone; and

displaying the obtained panoramic image by correcting the non-linearity of the initial image, performed by retrieving image points on the obtained image in a coordinate system of center O' using at least the non-linear distribution function and a size L of the obtained image.

Issue 1A

’990’s Description Relating to “correcting the non-linearity of the initial image … using at least the non-linear distribution function and **a** **<u>size L of the obtained image</u>**”

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DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

’990 Patent: Image Distribution Function of a Classic Panoramic Objective Lens

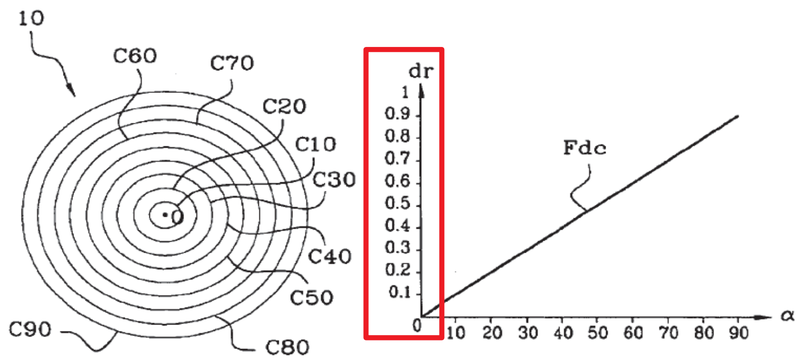

Fig. 4A

Fig. 4B

’990 Patent’s Specification

FIG. 4B represents the shape of the distribution function Fdc of a classical panoramic objective lens, which determines the relative distance dr of an image point in relation to the center of the image disk according to the field angle ax of the corresponding object point. The relative distance dr is between 0 and 1 and is equal to the distance of the image point in relation to the center of the image divided by the radius of the image disk. The ideal form of the function Fdc

APPLE-1023 (2nd Kessler Decl.), ¶¶ 77-80, 89-91; APPLE-1001, 2:30-41, FIGS. 4A-4B

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’990 Patent’s Non-Linear Distribution Function

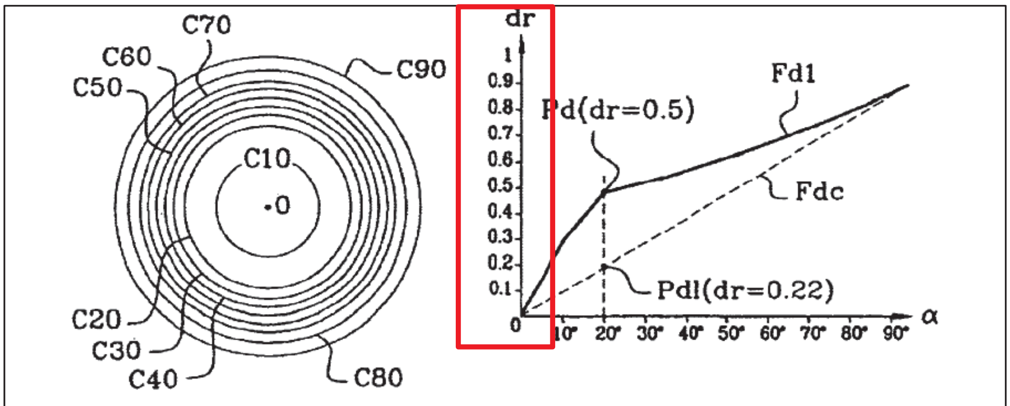

Fig. 7A

Fig. 7B

’990 Patent’s Specification

FIG. 4B represents the shape of the distribution function Fdc of a classical panoramic objective lens, which determines the relative distance dr of an image point in relation to the center of the image disk according to the field angle ax of the corresponding object point. The relative distance dr is between 0 and 1 and is equal to the distance of the image point in relation to the center of the image divided by the radius of the image disk. The ideal form of the function Fdc

APPLE-1023, ¶¶ 77-80, 89-91; APPLE-1001, 2:30-41, FIGS. 7A-7B

’990’s Non-Linear Distribution Function Identifies Normalized Image Heights/Distances at Different Field Angles

80. Thus, the above embodiments in the ’990 Patent’s specification use an image distribution function, referred to as Fd, that uses a normalized image size of 1 and therefore, identifies relative or normalized distances of image points ranging from 0 to 1. *See* EX-2001, ¶¶36-37 (ImmerVision’s expert acknowledged that (1) α-dr curve in the ’990 patent represents the claimed non-linear distribution function and (2) dr represents a “relative distance,” which is a “dimensionless” quantity that has values ranging from 0 to 1); APPLE-1025, 16:16-19:13, 20:2-21:8.

2nd Declaration of Dr. Kessler

89. The above can also be expressed simply in mathematical terms. An image distribution function, when normalized to have a radius/size of 1, represents a relationship between a relative image height (ranging from 0 to 1) and field angles (ranging from 0 to 90 degrees). *See also* EX-1025, 20:2-21:8, 16:16-17:4 (testifying that “relative distance is like a percentage” and represents a “normalized distance value”). The relative image height or distance of a particular point represents a radial distance or height of a particular point in the image plane divided by the radius of the image. Such a normalized distribution function therefore identifies a relative radial distance of a point in the image plane at a particular field angle (α):

$$(\textit{relative radial image}) = \frac{(\textit{radial distance})}{(\textit{image radius})} = Fd(\alpha)$$

See APPLE-1025, 14:14-17:16.

APPLE-1023, ¶¶80, 89.

Normalized Image Heights/Distances at Different Field Angles

2nd Declaration of Dr. Kessler

89. The above can also be expressed simply in mathematical terms. An image distribution function, when normalized to have a radius/size of 1, represents a relationship between a relative image height (ranging from 0 to 1) and field angles (ranging from 0 to 90 degrees). *See also* EX-1025, 20:2-21:8, 16:16-17:4 (testifying that "relative distance is like a percentage" and represents a "normalized distance value"). The relative image height or distance of a particular point represents a radial distance or height of a particular point in the image plane divided by the radius of the image. Such a normalized distribution function therefore identifies a relative radial distance of a point in the image plane at a particular field angle (α):

$$(\text{relative radial image}) = \frac{(\text{radial distance})}{(\text{image radius})} = Fd(\alpha)$$

See APPLE-1025, 14:14-17:16.

APPLE-1023, ¶¶80, 89.

Dep. Testimony of PO's Expert

Q. And just so I understand the relative distance concept, is it correct that it is relative in that it represents a radial distance of an image point at a particular field angle that is relative to the maximum radius of the image?

A. Yes, the relative distance is like a percentage. When you are halfway out in the image plane, to the maximum extent of the image, you are at, for example, a relative distance of 0.5.

Q. I see. Okay. And then the values of this relative distance effectively range from 0 to 1; is that right.

A. Correct.

Q. So, in a way, the relative distance is a normalized distance value. Is that fair?

A. That is correct, yes.

APPLE-1025, 16:16-17:11; APPLE-1023, ¶¶80, 89.

’990’s Image Transformation Algorithm Multiplies Image Distribution Function by Image Size/Radius L

’990 Patent

Algorithm 2

```
For i=−Imax/2 to i=Imax/2 do [by increments of 1]
    For j=−Jmax/2 to j=Jmax/2 do [by increments of 1]
[calculation of the Cartesian coordinates Ex, Ey, Ez
of the point E of the display window in the system OXYZ]
        Ey = j*cos(φ0) − Zoom*sin(φ0)
        Ez = Zoom*cos(φ0) + j*sin(φ0)
        aux1 = Ez
        Ez = Ez*cos(θ0) − i*sin(θ0)
        Ex = i*cos(θ0) + aux1*sin(θ0)
[calculation of the coordinates of the point P corresponding to the point E]
        aux2 = R/√(Ex*Ex + Ey*Ey + Ez*Ez)
        Px = Ex*aux2
        Py = Ey*aux2
        Pz = Ez*aux2
[calculation of the coordinates of the point p corresponding
to the point P, in the coordinate system
(O'UV), by means of the function Fd]
        X = Px/R
        Y = Py/R
        r = √(X*X + Y*Y)
        α = arcsine(r)
        U = X/r
        V = Y/r
        pu = L*U*Fd(α)
        pv = L*V*Fd(α)
        Screen_Pixel[i,j] = Image_Pixel[pu,pv]
    end for
end for
```

APPLE-1025, 37:18-38:6, 16:5-15; APPLE-1001, 14:10-35; APPLE-1023, ¶¶84-85

Dep. Testimony of PO’s Expert

Q. What is the extent of the image produced by the lens?
A. The quantity L.
Q. And when you say the extent of the image produced by the lens, is that the extent from the optical axis?
A. Yes.

Q. What do you mean by the maximum radius of the image?
A. So, the lens produces an image, and it is typically a round image with an extent away from the optical axis.
The extent from the optical axis -- the maximum extent away from the optical access that the image occupies is that radius.
Q. So, it is effectively the radius of the circular image; is that right?
A. Correct.

Size L is Used For Scaling in the ’990 Patent

Dep. Testimony of PO’s Expert

Q. Sure. Because the FD alpha function is provided in relative terms, one would need to scale that using the image size to obtain the actual image point, correct?

MR. MURRAY: Same objection.

THE WITNESS: The actual image point, that is corrected.

BY MR. JHURANI:

Q. I see, yes. So, because the FD alpha is provided in relative terms, one would need to scale it using the image size to obtain the corrected image point, right?

A. Corrected, yes.

So how is that being performed in the context of Lines 18 and 19 of the algorithm?

A. Right. So, the quantity, U FD of alpha in Line 18, that is still unscaled -- I'm sorry. That is still scaled by FD of A, of alpha. So, FD of alpha still goes from 0 to 1.

So, multiplying by L removes that scaling and gives it a dimension.

Q. And so that uses the actual image height then as part of that scaling?

A. The size of the image disk, yes.

Q. So is the actual size of the image height not used for the scaling?

A. It is the extent of the image produced by the lens.

Q. What is the extent of the image produced by the lens?

A. The quantity L.

Q. And when you say the extent of the image produced by the lens, is that the extent from the optical axis?

A. Yes.

APPLE-1025, 39:1-7, 37:18-38:11; APPLE-1023, ¶¶56, 59, 83-85.

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Issue 1B

Baker-Shiota Renders Obvious “correcting the non-linearity of the initial image … using … a size L of the obtained image” similar to the ’990 Patent’s Description of This Feature

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Baker-Shiota Leverages Shiota's Image Transformation Teachings that Use a Non-Linear Image Distribution Function

Shiota

[0036] Since the height (h) from the origin on the fisheye image face (origin of the p, q coordinate system) to the point w is expressed as a function of θ_1 according to the fisheye image projecting method, the following equation (3) is satisfied.

$$h = F(\theta_1) \quad (3)$$

[0037] Some examples of specific functions of $F(\theta_1)$ according to the projecting method will be shown. When it is assumed that the focal distance of the fisheye lens is f, the following relations are established.

equidistant projection: $h = f \cdot \theta$

stereoscopic projection: $h = 2f \cdot \tan(\theta/2)$

'990 Reexamination

F. Baker and Shiota

Baker teaches a camera with a lens for capturing a hemispheric scene, emphasizing the periphery of the image. A person of ordinary skill in the art would recognize the need to correct the image captured by Baker. Shiota, in the same field of endeavor, teaches a method of transforming a captured image into a plane image for display using the non-linear distribution function. Thus, one of ordinary skill in the art would have had reason to consult Shiota for a method of de-warping the image captured by the panoramic lens of Baker for presentation to a user.

1st Declaration of Dr. Kessler

201. For reasons described in §§VIII.B and X.A and in [27e] (incorporated here by reference), a POSITA would have found it obvious to implement Shiota's image transformation techniques in combination with Baker, to transform and display a non-linear panoramic image captured with Baker's objective lens in a "proper aspect ratio" to provide a "perspective corrected view," as contemplated by Baker. APPLE-1006, 14:18-26.

202. Specifically, the Baker-Shiota combination would have relied upon Shiota's teachings that describe image correction by applying a correction coefficient (k_2)—which is determined based on a non-linear image distribution function—to the captured image to obtain transformed image points that compensate for the distortion in the captured image. APPLE-1012, [0022]-[0024]. Specifically, the equation for determining the correction coefficient is $k_2 = h/r$, where h represents the lens image distribution function and r is the distance from the origin of an X, Y, Z coordinate system to the projected point on the image plane. APPLE-1012, [0037]-[0042].

203. Again, Patent Owner has acknowledged that these disclosures in Shiota teach correcting the non-linearity of the initial image using a non-linear distribution function. APPLE-1011, 234, 117.

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APPLE-1012, [0032]-[0042]; APPLE-1003, ¶¶191-204; APPLE-1023, ¶¶81-91; APPLE-1011, 234, 117

Shiota Describes Normalizing Image Size/Radius to 1

Shiota

[0023] A plane image (fisheye image) obtained through the fisheye lens is expressed by a (p, q) coordinate system as shown in Fig. 1. It is assumed that the (p, q) coordinate system is parallel to the (X, Y) plane and has the origin on the Z axis. In a position on an image pickup face (for example, position of a pixel on a CCD image pickup device), the image circle diameter differs according to the size of the image pickup device and the focal distance of the fisheye lens. Consequently, it is assumed that a fisheye image is projected in a circle of radius 1 of an image of an object positioning at 90 degrees (Z = 0) from the front of the lens. At the time of actually use, magnification adjustment is performed.

APPLE-1012, [0023]; APPLE-1003, ¶¶205-206; APPLE-1023, ¶¶55-56, 61-63, 81

1st Declaration of Dr. Kessler

205. The combination would have also rely upon Shiota's teaching of using the actual size of the image in performing the above-described image transformation. For its described image transformation operations, Shiota assumes a normalized radius of 1 of the image circle at a field angle of 90° (from the front of the lens). APPLE-1012, [0023]. However, Shiota acknowledges that the image circle diameter (i.e., the size of the image) "differs according to at least the size of the image pickup device" and that "at the time of actual[] use, magnification adjustment is performed." *Id.* A POSITA would have thus understood that this reference to "magnification adjustment" refers to an adjustment that accounts for the actual size of the image pickup device—and by extension, the actual size of the image—as part of the image transformation. *See also* APPLE-1012, [0025]-[0026] (explaining that

2nd Declaration of Dr. Kessler

55. Shiota further states that the image size or radius, which is image height, h, at a field angle of 90 degrees, is normalized to 1. APPLE-1012, [0023]; APPLE-1003, ¶¶205-206. Specifically, Shiota states that "it is assumed that a fisheye image is projected in a circle of radius 1 of an image of an object position[ed] at 90 degrees (Z=0) from the front of the lens." APPLE-1012, [0023]. Thus, the height of the image (h = f(θ) or h = 2f * tan(θ/2), where θ = 90 degrees) is 1 when the radius is

The Experts Agree that Using a Normalizing Image Size of 1 is “Commonly Done” in “Optics and Lens Design”

Fisher (APPLE-1009)

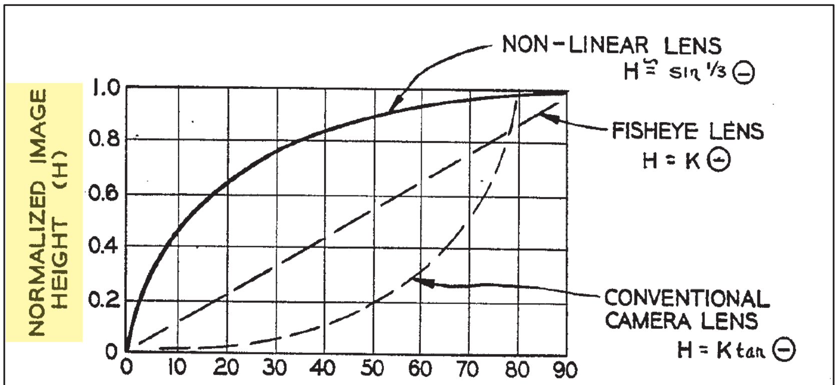

FIG. 3

APPLE-1009, FIGS. 3-4; APPLE-1023, ¶57; APPLE-1025, 21:9-22:8

Dep. Testimony of PO’s Expert

Q. Why is this relationship between field angle and image height shown with respect to the relative height or distance and not the actual radial distance of the image points?

A. So, when it is normalized from 0 to 1, it makes the math more generic, more applicable to a wider range of lens configurations. And this is commonly done throughout the field of optics and lens design.

Patent Owner's Expert Explained Why Image Size is Commonly Normalized to 1 in the Field of Optics

Dep. Testimony of PO's Expert

Q. Why is this relationship between field angle and image height shown with respect to the relative height or distance and not the actual radial distance of the image points?

A. So, when it is normalized from 0 to 1, it makes the math more generic, more applicable to a wider range of lens configurations. And this is commonly done throughout the field of optics and lens design.

Q. Why do you say that it makes the math more generic?

A. Because it makes it independent of the actual image size. It is just standardized to 1. And when we design a lens, for example, the different aberrations, spherical, conal, what not, they come into play at different ranges, from 0 to 1.

And when we always have to deal from a range of 0 to 1, it is just really easier to communicate, you know, higher field angles, or, excuse me, higher image heights on that scale of 0 to 1. It is just the way it works out.

Q. And so, the benefit, if I am understanding correctly, of using these relative or normalized distance values is that it allows generalizing across different types of lens configurations.

Is that correct?

A. That's correct.

APPLE-1025, 21:9-22:8, 24:4-24:10; APPLE-1023, ¶¶57-59.

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Shiota's Description Generalizes the Algorithm For Different Image Sizes by Using a Normalized Image Size of 1

Shiota

[0023] A plane image (fisheye image) obtained through the fisheye lens is expressed by a (p, q) coordinate system as shown in Fig. 1. It is assumed that the (p, q) coordinate system is parallel to the (X, Y) plane and has the origin on the Z axis. In a position on an image pickup face (for example, position of a pixel on a CCD image pickup device), the image circle diameter differs according to the size of the image pickup device and the focal distance of the fisheye lens. Consequently, it is assumed that a fisheye image is projected in a circle of radius 1 of an image of an object positioning at 90 degrees (Z = 0) from the front of the lens. At the time of actually use, magnification adjustment is performed.

APPLE-1003, ¶¶205-206; APPLE-1023, ¶¶55-59, 81-85; EX-2001, ¶51

Given Normalized Image Size of 1, Shiota's Non-Linear Distribution Function Generates Values on a Scale of 0 to 1

Shiota

[0036] Since the height (h) from the origin on the fisheye image face (origin of the p, q coordinate system) to the point w is expressed as a function of θ_1 according to the fisheye image projecting method, the following equation (3) is satisfied.

$$h = F(\theta_1) \quad (3)$$

[0037] Some examples of specific functions of $F(\theta_1)$ according to the projecting method will be shown. When it is assumed that the focal distance of the fisheye lens is f, the following relations are established.

equidistant projection: $h = f \cdot \theta$

stereoscopic projection: $h = 2f \cdot \tan(\theta/2)$

APPLE-1023, ¶¶ 55-56; APPLE-1003, ¶¶191-206; APPLE-1012, [0036]-[0037]

Second Declaration of Dr. Kessler

55. Shiota further states that the image size or radius, which is image height, h, at a field angle of 90 degrees, is normalized to 1. APPLE-1012, [0023]; APPLE-1003, ¶¶205-206. Specifically, Shiota states that "it is assumed that a fisheye image is projected in a circle of radius 1 of an image of an object position[ed] at 90 degrees (Z=0) from the front of the lens." APPLE-1012, [0023]. Thus, the height of the image (h = f(θ) or h = 2f * tan(θ/2), where θ = 90 degrees) is 1 when the radius is

assumed/normalized to 1. *See* APPLE-1012, [0036]-[0037] (showing and describing image distribution functions for computing image height of particular coordinates at particular field angles).

56. Because Shiota's image distribution function uses a normalized image size/radius of 1, this function therefore identifies heights of image points normalized on a scale ranging from 0 to 1. APPLE-1003, ¶¶205-206; APPLE-1025, 15:5-17:8. In other words, because image height or distance is computed using a function that uses a normalized image size of 1, the image height/distance using Shiota's image distribution function would be provided in relative terms, on a scale ranging from 0 to 1. Note that image size is a well-recognized term in the fields of optics and optical

Image Coordinates Computed in Shiota Are Provided in Relative/Normalized Terms

Shiota

[0036] Since the height (h) from the origin on the fisheye image face (origin of the p, q coordinate system) to the point w is expressed as a function of θ_1 according to the fisheye image projecting method, the following equation (3) is satisfied.

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equidistant projection: $h = f \cdot \theta$

stereoscopic projection: $h = 2f \cdot \tan(\theta/2)$

[0041] That is, the coefficient k_2 of the equation (2) can be derived as a function of Z_2. With respect to the coefficient k_2, a lookup table for obtaining the coefficient k_2 from the value of Z_2 in accordance with the equation (3) is generated. By using the value, second projection coordinates (p_1, q_1) on the image pickup face are obtained as follows.

$$p_1 = k_2 \cdot X_2$$
$$q_1 = k_2 \cdot Y_2$$

PO Sur-Reply

POR at 18-19. The algorithm concludes by obtaining "second projection coordinates (p_1, q_1) on the image pickup face" using coefficient k_2 and coordinates X_2, Y_2 from point P' on the hemisphere. Ex. 1012 at ¶¶ [0033]-[0042]; Ex. 2001 at ¶ 44; POR at 10; Ex. 2006 at 64:2-5, 67:4-7. As Dr. Kessler admits, k_2, X_2, and Y_2 are all normalized (or dimensionless), meaning p_1 and q_1, are normalized as well. Ex. 2006 at 57:21-58:7, 69:5-6, 70:3-71:6; Ex. 2001 at ¶ 44. Shiota's p_1 and q_1 do

disputed (Reply at 8-13). Dr. Kessler admits that the calculation in Shiota's algorithm to obtain the final p_1, q_1 coordinates relies entirely upon normalized (or otherwise dimensionless) values – meaning p_1, q_1 are themselves normalized/dimensionless. Ex. 2006 at 57:21-58:7, 69:5-6, 70:3-71:6; *see also* Ex. 2001 at ¶ 44. It would be unusual for a POSA to understand Shiota to suggest using image size for obtaining coordinates when the stated algorithm outputs dimensionless coordinates and "magnification" is also typically considered dimensionless. Ex. 2001 at ¶ 52; POR at 15-16. This is why Mr. Munro

APPLE-1012, [0036]-[0041]; APPLE-1023, ¶¶60-63, 77-91; Sur-Reply, 6, 11.

When Using a Normalized Image Size, Scaling Would be Done to Account for the Image Size in an Actual Application

Smith (APPLE-1026)

Thus one can look at the aberration plots for a given design and, by applying the techniques outlined above, easily visualize what they will look like after an adjustment has been made to fit the design to the application at hand.

5.4 Scaling a Design, Its Aberrations, and Its MTF

A lens prescription can be scaled to any desired focal length simply by multiplying all of its dimensions by the same constant. All of the *linear* aberration measures will then be scaled by the same factor. Note however, that percent distortion, chromatic difference of magnification (CDM), the numerical aperture or *f* number, aberrations expressed as angular aberrations, and any other *angular* characteristics remain completely unchanged by scaling.

APPLE-1026, 57; APPLE-1025, 23:14-24:10; APPLE-1023, ¶¶57-59, 86-91.

Dep. Testimony of PO's Expert

Q. No worries. So, I believe you said that the math is made more generic because it is now independent of the actual image size and standardized to 1.

A. Uh-huh.

Q. And, you are saying -- I'm just saying what is standardized to 1?

A. The image height.

Q. Okay. Why does using the image height of 1 make it independent of the actual image size?

A. So, it is a relative height. So, it is the location in the image -- the radial distance in the image divided by the maximum extent of the image. So, it is just scaled so it ranges from 0 to 1.

Q. And so when you are considering an actual application, then you would have to scale up to account for the actual image size?

A. That is true, yes.

Shiota's "Magnification Adjustment" Accounts for the Image Size in "Actual[] Use"

Shiota

[0023] A plane image (fisheye image) obtained through the fisheye lens is expressed by a (p, q) coordinate system as shown in Fig. 1. It is assumed that the (p, q) coordinate system is parallel to the (X, Y) plane and has the origin on the Z axis. In a position on an image pickup face (for example, position of a pixel on a CCD image pickup device), the image circle diameter differs according to the size of the image pickup device and the focal distance of the fisheye lens. Consequently, it is assumed that a fisheye image is projected in a circle of radius 1 of an image of an object positioning at 90 degrees (Z = 0) from the front of the lens. At the time of actually use, magnification adjustment is performed.

APPLE-1012, [0023]; APPLE-1003, ¶¶205-206, 77-91.

1st Declaration of Dr. Kessler

205. The combination would have also rely upon Shiota's teaching of using the actual size of the image in performing the above-described image transformation. For its described image transformation operations, Shiota assumes a normalized radius of 1 of the image circle at a field angle of 90° (from the front of the lens). APPLE-1012, [0023]. However, Shiota acknowledges that the image circle diameter (i.e., the size of the image) "differs according to at least the size of the image pickup device" and that "at the time of actual[] use, magnification adjustment is performed." *Id.* A POSITA would have thus understood that this reference to "magnification adjustment" refers to an adjustment that accounts for the actual size of the image pickup device—and by extension, the actual size of the image—as part of the image transformation. *See also* APPLE-1012, [0025]-[0026] (explaining that

necessary parameters for the image transformation operations include, e.g., the magnification of the image), [0024] (using "the scale factor (zoom ratio) as the size of the plane image" to perform the described image transformation).

206. Thus, a POSITA would have understood or found obvious that the image transformation described in Shiota, when applied to an actual application accounts for the size of the actual image for the underlying image transformation. Moreover, given that the size of the image pickup device (and by extension the size of the image) varies depending on the implementation, a POSITA would have found it obvious to use the actual size of the image—as applicable in Baker's system—as part of the image transformation to generate a properly compensated/transformed image for display.

FISH.

Patent Owner Omits Key Disclosures in Shiota's Paragraph 23

PO Expert Declaration (EX-2001)

51. Petitioner and Dr. Kessler do not point to any such disclosure in Shiota because Shiota is silent on the use of image size. APPLE 1003, ¶¶ 199-212. Instead, they rely on paragraph 23 in Shiota, which teaches "… a fisheye image is projected in a circle of radius 1 of an image of an object positioning at 90 degrees (Z=0) from the front of the lens. At the time of actual use, magnification adjustment is performed". In this text no mention is made of the size of the image,

Shiota

[0023] A plane image (fisheye image) obtained through the fisheye lens is expressed by a (p, q) coordinate system as shown in Fig. 1. It is assumed that the (p, q) coordinate system is parallel to the (X, Y) plane and has the origin on the Z axis. In a position on an image pickup face (for example, position of a pixel on a CCD image pickup device), the image circle diameter differs according to the size of the image pickup device and the focal distance of the fisheye lens. Consequently, it is assumed that a fisheye image is projected in a circle of radius 1 of an image of an object positioning at 90 degrees (Z = 0) from the front of the lens. At the time of actually use, magnification adjustment is performed.

1st Declaration of Dr. Kessler

205. The combination would have also rely upon Shiota's teaching of using the actual size of the image in performing the above-described image transformation. For its described image transformation operations, Shiota assumes a normalized radius of 1 of the image circle at a field angle of 90° (from the front of the lens). APPLE-1012, [0023]. However, Shiota acknowledges that the image circle diameter (i.e., the size of the image) "differs according to at least the size of the image pickup device" and that "at the time of actual[] use, magnification adjustment is performed." *Id.* A POSITA would have thus understood that this reference to "magnification adjustment" refers to an adjustment that accounts for the actual size of the image pickup device—and by extension, the actual size of the image—as part of the image transformation. *See also* APPLE-1012, [0025]-[0026] (explaining that

necessary parameters for the image transformation operations include, e.g., the magnification of the image), [0024] (using "the scale factor (zoom ratio) as the size of the plane image" to perform the described image transformation).

APPLE-1012, [0023]; APPLE-1003, ¶¶205-206; EX-2001, ¶51; APPLE-1023, ¶¶50-53

Patent Owner Omits Key Disclosures in Shiota's Paragraph 23

1st Declaration of Dr. Kessler

205. The combination would have also rely upon Shiota's teaching of using the actual size of the image in performing the above-described image transformation. For its described image transformation operations, Shiota assumes a normalized radius of 1 of the image circle at a field angle of 90° (from the front of the lens). APPLE-1012, [0023]. However, Shiota acknowledges that the image circle diameter (i.e., the size of the image) "differs according to at least the size of the image pickup device" and that "at the time of actual[] use, magnification adjustment is performed." *Id.* A POSITA would have thus understood that this reference to "magnification adjustment" refers to an adjustment that accounts for the actual size of the image pickup device—and by extension, the actual size of the image—as part of the image transformation. *See also* APPLE-1012, [0025]-[0026] (explaining that necessary parameters for the image transformation operations include, e.g., the magnification of the image), [0024] (using "the scale factor (zoom ratio) as the size of the plane image" to perform the described image transformation).

206. Thus, a POSITA would have understood or found obvious that the image transformation described in Shiota, when applied to an actual application accounts for the size of the actual image for the underlying image transformation. Moreover, given that the size of the image pickup device (and by extension the size of the image) varies depending on the implementation, a POSITA would have found it obvious to use the actual size of the image—as applicable in Baker's system—as part of the image transformation to generate a properly compensated/transformed image for display.

APPLE-1012, [0023]; APPLE-1003, ¶¶205-206; APPLE-1023, ¶¶50-56, 61-63

FISH.

Operator Selected Parameters in Shiota's Paragraph 24-26 Do Not Relate to the Obtained Fisheye Image

Shiota

[0024] An image is transformed as follows. The projecting position on the image pickup face (p, q coordinates) of a point (u, v coordinates) on a plane image is obtained by arithmetic operation. By referring to luminance information at the point, data of the plane image to be obtained can be generated. Information of the view points (φ, θ, α) and the scale factor (zoom ratio) as the size of the plane image is information inputted by the operator through a keyboard, pointing device, or the like and is obtained and set in advance as data for calculation by a higher-order arithmetic processing unit.

[0026] The parameters can be easily obtained from the information of the angle information (φ, θ, α) of the view point and the magnification of the image.

POR

magnification of the image." Ex. 1012 at ¶ [0026]; Ex. 2001 at ¶ 55. Paragraph [0026] is easily understood to be referring back to the operator-entered information from paragraph [0024], *all relating to the plane image for display*. Ex. 2001 at ¶ 55.

With Dr. Kessler confirming that the discussion within Shiota's paragraphs [0023]-[0026] is related, and the clear context that "magnification" and "scale factor (zoom ratio)" discussed in these passages refer to operator-selectable properties of the final image to be displayed, a POSA would not reach the conclusion that Shiota's discussion of "magnification" here relates to using the size of the fisheye image to retrieve image points for performing distortion correction operations. Ex. 2001 at ¶ 56; Ex. 1003 at ¶ 205. Rather, a POSA would have

2nd Declaration of Dr. Kessler

66. Moreover, ImmerVision and its expert acknowledge that these allegedly operator-selected parameters in paragraphs 24 to 26 of Shiota relate to the "plane image" referenced in Shiota (expressed in u,v coordinates) (*see* POR, 17-19; EX-2001, ¶¶53-56)—and not to the obtained image on the image pickup face (expressed in p, q coordinates) that Shiota refers to as the "fisheye image." APPLE-1012, [0023]-[0024].

POR, 19; APPLE-1023, ¶66; APPLE-1012, [0023]-[0026].

Shiota's Paragraph 23 Would Be Understood as Relating to the Obtained Fisheye Image

2nd Declaration of Dr. Kessler

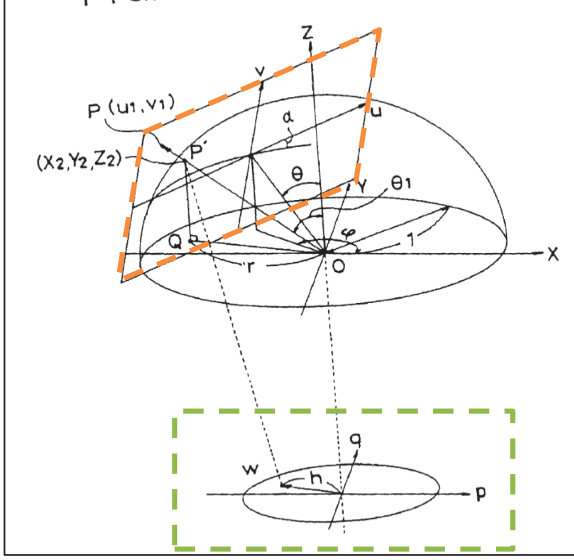
66. Moreover, ImmerVision and its expert acknowledge that these allegedly operator-selected parameters in paragraphs 24 to 26 of Shiota relate to the "plane image" referenced in Shiota (expressed in u,v coordinates) (*see* POR, 17-19; EX-2001, ¶¶53-56)—and not to the obtained image on the image pickup face (expressed in p, q coordinates) that Shiota refers to as the "fisheye image." APPLE-1012, [0023]-[0024].

67. However, paragraph 23 of Shiota confirms that the Shiota's references to the "image circle diameter," the normalized/assumed radius of 1 of the projected "circle," and the "magnification adjustment" due to "the image circle diameter differ[ing] according to the size of the image pickup device"—all relate to the fisheye image obtained on the image pickup device and represented using (p,q) coordinates (which corresponds to the "obtained image" on the "image sensor," as recited in claim 27). APPLE-1003, ¶¶205-206; *see id.*, APPLE-1012, [0023]-[0024].[2]

Shiota

[0023] A plane image (fisheye image) obtained through the fisheye lens is expressed by a (p, q) coordinate system as shown in Fig. 1. It is assumed that the (p, q) coordinate system is parallel to the (X, Y) plane and has the origin on the Z axis. In a position on an image pickup face (for example, position of a pixel on a CCD image pickup device), the image circle diameter differs according to the size of the image pickup device and the focal distance of the fisheye lens. Consequently, it is assumed that a fisheye image is projected in a circle of radius 1 of an image of an object positioning at 90 degrees (Z = 0) from the front of the lens. At the time of actually use, magnification adjustment is performed.

FIG. 1



APPLE-1023, ¶¶66-67; APPLE-1012, [0023], Fig. 1; APPLE-1003, ¶¶208-212

Shiota's "Magnification Adjustment" Accounts for the Image Size in "Actual[] Use"

2nd Declaration of Dr. Kessler

61. In particular, I explained in my first declaration that Shiota uses the non-linear distribution function in computing its correction coefficient (k_2) that is used to obtain corrected image points for display. APPLE-1003, ¶202 (citing APPLE-1012, ¶¶[0022]-[0024], [0037]-[0042]). Although the heights of the image points obtained using this distribution function are normalized values (given that the function uses a normalized image size/radius 1), Shiota also recognizes that, as part of its image transformation, "projection coordinates" (image points) on the "image pickup face are obtained …." APPLE-1012, [0023], [0036]-[0042]; APPLE-1003, ¶¶191-213. A POSITA would have therefore recognized that, retrieving the coordinates/points on the image pickup face (and within the projected image circle) would involve retrieving image points on the actual image circle projected on an actual image sensor/image pickup device—and not the image circle that has a radius/size normalized to 1. *See id.*

62. This is expressly acknowledged by Shiota when it states that "[i]n a position on an image pickup face (for example, position of a pixel on a CCD image pickup device), the ***image circle diameter differs according to the size of the image pickup device and the focal distance of the fisheye lens***." APPLE-1012, [0023]; APPLE-1003, ¶¶205-206. And, as a result, although Shiota normalizes the image circle to a radius of 1, Shiota unequivocally states that "magnification adjustment is performed" "[a]t the time of actual[] use" to account for the differing image circle diameter (which differs according to image sensor size) in an actual application/use of Shiota's system. *Id.*

APPLE-1012, [0023], [0036]-[0042]; APPLE-1003, ¶¶191-213; APPLE-1023, ¶¶61-62, 77-91.

FISH.

Shiota's "Magnification Adjustment" Accounts for the Image Size in "Actual[] Use"

2nd Declaration of Dr. Kessler

$$(\,relative\ radial\ image\,) = \frac{(\,radial\ distance\,)}{(\,image\ radius\,)} = Fd(\,\alpha)$$

See APPLE-1025, 14:14-17:16.

90. It follows then that to obtain the actual radial distance of that image point would simply involve multiplying the relative radial distance by the actual radial distance.

*(Image radius) * (relative radial distance) = (radial distance)*

91. In summary, when Shiota's techniques, as applied in combination with Baker and applied in an actual use/implementation, a POSITA would have found obvious to scale the obtained image points using the normalized distribution function (where the image heights are normalized using an image size of 1) with the actual image size/radius (e.g., as measured in pixels)—and thereby retrieve the actual, corrected/transformed image points as projected on an actual image circle/disk.

APPLE-1003, ¶¶191-213; APPLE-1023, ¶¶89-91

Appendix 1

Rebuttals to Patent Owner's Arguments

Patent Owner's Narrative Regarding the Preliminary Proceedings Ignores Focus on Shiota's Paragraph 23

Rebuttal to: *"To obtain institution, Petitioner unequivocally relied on paragraphs [0024]-[0026] for its interpretation of paragraph [0023]" and without paragraphs [0024]-[0026], Petitioner is left "scrambling for evidence." Sur-Reply, 1.*

POPR

The sole alleged error that can be gleaned from the Petition is a supposed failure by the examiner to consider Shiota's paragraph [0023], and to a lesser extent, paragraphs [0024]-[0026]. Petition at 77-78. Petitioner accused Patent Owner of leading the examiner away from these passages through citation to supposedly less relevant paragraphs later in the reference. *Id.*

First, Petitioner cited no authority holding an examiner is only deemed to have considered portions of a reference cited by others. Second, the record demonstrates the examiner fully evaluated Shiota. For example, when describing the patentable subject matter in claim 27, the examiner cited to Shiota's paragraphs [0001], [0022], and [0028]-[0041]. Ex. 1011 at 323. In the detailed explanation of pertinency, Patent Owner highlighted Shiota's paragraphs [0024], [0030]-[0035], [0037]-[0042], and [0049]. Ex. 1011 at 117-118. The examiner cited and/or was directed to paragraphs in Shiota immediately surrounding and including portions of the description Petitioner alleges are relevant. There is no evidence the examiner skipped over the identified paragraphs in Shiota, particularly when the description around it was explicitly under review for the feature at issue here (size L of the obtained image as a factor in correcting non-linearity).

POPR, 19

Petitioner's Pre-Institution Reply

As the Petition explains, the '990's prosecution did not reference ¶ 23 of Shiota (shown below; annotated), which provides that (1) image size (referred to as image circle diameter) differs according to the image pickup device's size, and (2) the image transformation operations assume the image's size as 1 and perform "magnification adjustment" in "actual[] use" where the image and image pickup device may have different sizes. Petition, 50-51, 77-78. Petitioner highlights the significance of this unrecognized disclosure, offering expert testimony explaining how a POSITA reading this

> **[0023]** A plane image (fisheye image) obtained through the fisheye lens is expressed by a (p, q) coordinate system as shown in Fig. 1. It is assumed that the (p, q) coordinate system is parallel to the (X, Y) plane and has the origin on the Z axis. In a position on an image pickup face (for example, position of a pixel on a CCD image pickup device), the image circle diameter differs according to the size of the image pickup device and the focal distance of the fisheye lens. Consequently, it is assumed that a fisheye image is projected in a circle of radius 1 of an image of an object positioning at 90 degrees (Z = 0) from the front of the lens. At the time of actually use, magnification adjustment is performed.

The Examiner's reasons for allowance identified ¶¶ 1, 22, and 28-41 in Shiota. APPLE-1011, 323. The Examiner thus broadened her review of Shiota beyond ¶¶ 33-41 identified by ImmerVision, and considered additional paragraphs (1, 22, 28-32). Yet, the Examiner did not identify any of Shiota's disclosures (¶¶ 23-26) that are relied upon in the Petition for the relevant claim 27 feature, nor did she address/mention the pertinent teachings of "magnification adjustment" in actual use and the image circle diameter differing due to the size of the image pickup device. These teachings are also not addressed in the additional paragraphs identified by the Examiner.

Preliminary Reply, 1, 5

Patent Owner's "Link[ing]" Argument Also Ignores Focus on Shiota's Paragraph 23

Rebuttal to: *"Dr. Kessler himself links together multiple references to "magnification" and other synonyms (i.e., 'scale factor' and 'zoom ratio')" in paragraphs 24 and 26 of Shiota with "magnification adjustment" in Shiota's paragraph 23.* POR, 1.

Shiota

[0023] A plane image (fisheye image) obtained through the fisheye lens is expressed by a (p, q) coordinate system as shown in Fig. 1. It is assumed that the (p, q) coordinate system is parallel to the (X, Y) plane and has the origin on the Z axis. In a position on an image pickup face (for example, position of a pixel on a CCD image pickup device), the image circle diameter differs according to the size of the image pickup device and the focal distance of the fisheye lens. Consequently, it is assumed that a fisheye image is projected in a circle of radius 1 of an image of an object positioning at 90 degrees (Z = 0) from the front of the lens. At the time of actually use, magnification adjustment is performed.

1st Declaration of Dr. Kessler

205. The combination would have also rely upon Shiota's teaching of using the actual size of the image in performing the above-described image transformation. For its described image transformation operations, Shiota assumes a normalized radius of 1 of the image circle at a field angle of 90° (from the front of the lens). APPLE-1012, [0023]. However, Shiota acknowledges that the image circle diameter (i.e., the size of the image) "differs according to at least the size of the image pickup device" and that "at the time of actual[] use, magnification adjustment is performed." *Id.* A POSITA would have thus understood that this reference to "magnification adjustment" refers to an adjustment that accounts for the actual size of the image pickup device—and by extension, the actual size of the image—as part of the image transformation. *See also* APPLE-1012, [0025]-[0026] (explaining that necessary parameters for the image transformation operations include, e.g., the magnification of the image), [0024] (using "the scale factor (zoom ratio) as the size of the plane image" to perform the described image transformation).

APPLE-1003, ¶205; APPLE-1023, ¶¶64-67; APPLE-1012, [0023].

FISH.

Patent Owner's Incorrect Linking of Shiota's Operator-Selected Parameters in Paragraphs 24-26 with Paragraph 23

Rebuttal to: *"Mr. Munro credibly interprets "magnification adjustment" at the end of paragraph [0023] within Shiota's overall context as referring to selecting portions for display, not correcting image distortion using the fisheye image size." Sur-Reply, 5.*

Declaration of Mr. Munro

operator through a keyboard…". This relates to the orientation and distance of the "plane image" (the displayed image having a u, v coordinate system) with respect to the hemispherical face. Shiota ¶¶ 22, 24, 28 The view point angles (φ, θ, α) are shown in Fig. 1 of Shiota and are chosen by the operator, as the operator selects which part of the overall image to view on the display. Shiota, ¶¶ 4, 24. Similarly, the operator will select a scale factor or zoom ratio as a size of the plane image. Shiota, ¶ 24. This is similar to the "enlargement (zoom)" operation described at column 14, lines 37-48, where the user selects a "zoom" parameter that moves the display window DW toward or away from the hemisphere HS to determine how much of the image is to be shown in the display window DW. In Shiota, since the plane image must have its center in contact with the hemisphere surface to enable the simplified calculations (Shiota, ¶ 22), a similar zoom effect can be achieved by allowing the operator to adjust the size of the plane image, which is how one of ordinary skill in the art would understand the "scale factor (zoom ratio)" description in paragraph 24.

'990 Patent

```
[calculation of the coordinates of the point p corresponding
to the point P, in the coordinate system
(O'UV), by means of the function Fd]
        X = Px/R
        Y = Py/R
        r = √(X*X + Y*Y)
        α = arcsine(r)
        U = X/r
        V = Y/r
        pu = L*U*Fd(α)
        pv = L*V*Fd(α)
        Screen_Pixel[i,j] = Image_Pixel[pu,pv]
    end for
  end for
```

A request for enlargement (zoom) by the user results in the algorithm modifying the "Zoom" parameter. When the "Zoom" parameter is equal to the radius R of the hemisphere, the display window DW is tangential to the hemisphere (FIG. 13). When the parameter "Zoom" is higher than R, the window DW moves away from the hemisphere (along the axis given by the viewing position 0M), which corresponds to a shrinking of the pyramid of vision and an enlargement of the image sector presented in the window DW. The enlargement of the image sector presented to the observer is therefore equal to the ratio of the "Zoom" parameter by the radius R.

EX-2001, ¶54 (citing APPLE-1001, 14:37-48 (shown on right)); APPLE-1003, ¶205; APPLE-1023, ¶¶64-67.

An Actual Application Would Not Use Normalized Coordinates, in View of Shiota and Baker

Rebuttal to: *"It would be unusual for a POSA to understand Shiota to suggest using image size for obtaining coordinates when the stated algorithm outputs dimensionless coordinates and "magnification" is also typically considered dimensionless." Sur-Reply, 6.*

2nd Declaration of Dr. Kessler

61. In particular, I explained in my first declaration that Shiota uses the non-linear distribution function in computing its correction coefficient (k_2) that is used to obtain corrected image points for display. APPLE-1003, ¶202 (citing APPLE-1012, ¶¶[0022]-[0024], [0037]-[0042]). Although the heights of the image points obtained using this distribution function are normalized values (given that the function uses a normalized image size/radius 1), Shiota also recognizes that, as part of its image transformation, "projection coordinates" (image points) on the "image pickup face are obtained …." APPLE-1012, [0023], [0036]-[0042]; APPLE-1003, ¶¶191-213. A POSITA would have therefore recognized that, retrieving the coordinates/points on the image pickup face (and within the projected image circle) would involve retrieving image points on the actual image circle projected on an actual image sensor/image pickup device—and not the image circle that has a radius/size normalized to 1. *See id.*

62. This is expressly acknowledged by Shiota when it states that "[i]n a position on an image pickup face (for example, position of a pixel on a CCD image pickup device), the ***image circle diameter differs according to the size of the image pickup device and the focal distance of the fisheye lens***." APPLE-1012, [0023]; APPLE-1003, ¶¶205-206. And, as a result, although Shiota normalizes the image circle to a radius of 1, Shiota unequivocally states that "magnification adjustment is performed" "[a]t the time of actual[] use" to account for the differing image circle diameter (which differs according to image sensor size) in an actual application/use of Shiota's system. *Id.*

APPLE-1023, ¶¶61-62, 83-91; APPLE-1012, [0023].

FISH.

Image Size and Image Sensor Size are Directly Related

Rebuttal to: *Size of the image sensor and of the image are "not so inextricably linked." POR, 15-16 n 3.*

"A POSA recognizes that image sensor size is not the same as image size…. [A]n image will not grow or shrink even if a larger or smaller sensor is substituted." Sur-Reply, 8-9.

2nd Declaration of Dr. Kessler

68. ***Fourth***, ImmerVision argues in footnote 1 of the POR that size of the image sensor and size of the image are "not so inextricably linked." POR, 15-16 n. 1; EX-2001, ¶58. I disagree. As a starting point, this assertion is refuted by Shiota, which teaches that the image circle diameter (which corresponds to the image size) differs according to the size of the image pickup device (i.e., the size of image sensor). APPLE-1012, [0023] ("In a position on an image pickup face (CCD image pickup device), the ***image circle diameter differs according to the size of the image pickup device*** and the focal distance of the fisheye lens."). Thus, Shiota itself teaches image size and sensor size are directly related.

69. That the image size may not be exactly the same as the size of the sensor is beside the point—and I did not claim such equality between sensor size and image size. APPLE-1003, ¶¶205-206.

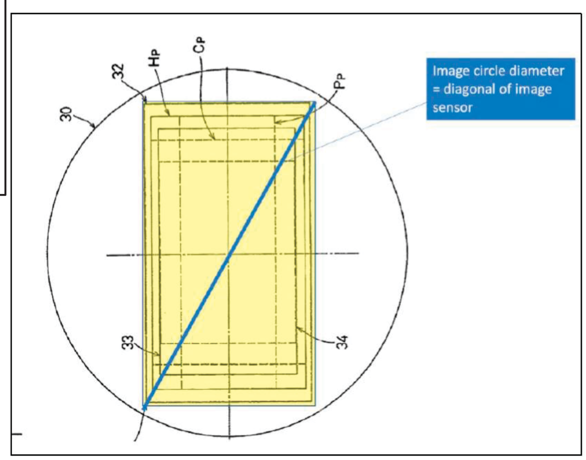
APPLE-1023, ¶¶68-69; APPLE-1012, [0023].

Image Size and Image Sensor Size are Directly Related

Rebuttal to: *"A POSA recognizes that image sensor size is not the same as image size….Petitioner attempted to discredit this testimony by pointing to an error in Mr. Munro's description of the '990 Patent's Fig. 2, in turn implying that only configurations where the sensor diagonal is essentially identical to the image circle diameter matter" Sur-Reply, 8-9.*

2nd Declaration of Dr. Kessler

70. Moreover, consistent with Shiota's teachings, a POSITA would have recognized the direct relationship between image size and sensor size. In fact, this is illustrated by the reference identified by Mr. Munro. Specifically, Mr. Munro identified Fig. 11 of U.S. Patent Application Publication US 2004/0201764 (EX-2005), which shows the image sensor (highlighted in yellow below) and image circle/image disk (annotated with blue line), as reproduced and annotated below.



APPLE-1023, ¶¶70-73; Ex. 2005 at Fig. 11, ¶ [0106]

Image Size and Image Sensor Size are Directly Related

Rebuttal to: *"Contrary to Petitioner's alleged causal link, even if one is performing an operation to 'account' for the size of an image sensor, the image disk size is not necessarily implicated." Sur-Reply, 9.*

1st Declaration of Dr. Kessler

206. Thus, a POSITA would have understood or found obvious that the image transformation described in Shiota, when applied to an actual application accounts for the size of the actual image for the underlying image transformation. Moreover, given that the size of the image pickup device (and by extension the size of the image) varies depending on the implementation, a POSITA would have found it obvious to use the actual size of the image—as applicable in Baker's system—as part of the image transformation to generate a properly compensated/transformed image for display.

2nd Declaration of Dr. Kessler

63. Thus, given Shiota's express teaching that size of the image pickup device (and by extension size of the image) varies/differs depending on the implementation, and because Shiota's image transformation is illustrated using a normalized image size of 1, my testimony was and remains that "a POSITA would have found it obvious" to perform scaling or "magnification adjustment"—which, again, was common and conventional in optics—by "us[ing] the actual size of the image" to obtain the corrected image points for display. *Id.*

73. Thus, consistent with Shiota's teaching, a POSITA in this field would have readily understood that the image circle diameter differs according to (and therefore is directly related to) the size of the rectangular image pickup/sensor.

APPLE-1023, ¶¶63, 70-75, APPLE-1003, ¶206

Patent Owner's Flawed Comparison to the '990 Specification

Rebuttal to: *"The '990 Patent uses the image size to retrieve image points and includes that value in the example algorithm. Shiota's algorithm contains no such variable and, therefore, does not support Petitioner's interpretation of 'magnification.'" Sur-Reply, 11*

Excerpts from Shiota

[0023] A plane image (fisheye image) obtained through the fisheye lens is expressed by a (p, q) coordinate system as shown in Fig. 1. It is assumed that the (p, q) coordinate system is parallel to the (X, Y) plane and has the origin on the Z axis. In a position on an image pickup face (for example, position of a pixel on a CCD image pickup device), the image circle diameter differs according to the size of the image pickup device and the focal distance of the fisheye lens. Consequently, it is assumed that a fisheye image is projected in a circle of radius 1 of an image of an object positioning at 90 degrees (Z = 0) from the front of the lens. At the time of actually use, magnification adjustment is performed.

1st Declaration of Dr. Kessler

205. The combination would have also rely upon Shiota's teaching of using the actual size of the image in performing the above-described image transformation. For its described image transformation operations, Shiota assumes a normalized radius of 1 of the image circle at a field angle of 90° (from the front of the lens). APPLE-1012, [0023]. However, Shiota acknowledges that the image circle diameter (i.e., the size of the image) "differs according to at least the size of the image pickup device" and that "at the time of actual[] use, magnification adjustment is performed." *Id.* A POSITA would have thus understood that this reference to "magnification adjustment" refers to an adjustment that accounts for the actual size of the image pickup device—and by extension, the actual size of the image—as part of the image transformation. *See also* APPLE-1012, [0025]-[0026] (explaining that necessary parameters for the image transformation operations include, e.g., the magnification of the image), [0024] (using "the scale factor (zoom ratio) as the size of the plane image" to perform the described image transformation).

APPLE-1012, [0023]; APPLE-1003, ¶¶205-206; APPLE-1023, ¶¶81-93.

Appendix 2

Overview of the ’990 Patent

FISH.

Overview

US006844990B2

(12) **United States Patent**
Artonne et al.

(10) **Patent No.: US 6,844,990 B2**
(45) **Date of Patent: Jan. 18, 2005**

(54) **METHOD FOR CAPTURING AND DISPLAYING A VARIABLE RESOLUTION DIGITAL PANORAMIC IMAGE**

(75) Inventors: **Jean-Claude Artonne**, Montreal (CA); **Christophe Moustier**, Marseilles (FR); **Benjamin Blanc**, Montreal (CA)

(73) Assignee: **6115187 Canada Inc.**, Saint Laurent (CA)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/706,513**

(22) Filed: **Nov. 12, 2003**

(65) **Prior Publication Data**

US 2004/0136092 A1 Jul. 15, 2004

Related U.S. Application Data

(63) Continuation of application No. PCT/FR02/01588, filed on May 10, 2002.

(30) **Foreign Application Priority Data**

May 11, 2001 (FR) 01 06261

(51) **Int. Cl.**[7] **G02B 13/06**; G02B 13/18
(52) **U.S. Cl.** **359/725**; 359/718
(58) **Field of Search** 359/718, 719, 359/725, 728

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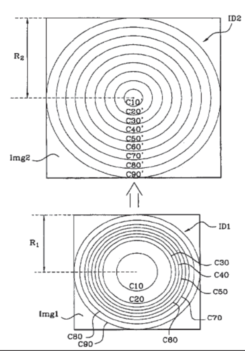
(57) **ABSTRACT**

A method for capturing a digital panoramic image includes projecting a panorama onto an image sensor by means of a panoramic objective lens. The panoramic objective lens has a distribution function of the image points that is not linear relative to the field angle of the object points of the panorama, such that at least one zone of the image obtained is expanded while at least another zone of the image is compressed. When a panoramic image obtained is then displayed, correcting the non-linearity of the initial image is required and is performed by means of a reciprocal function of the non-linear distribution function of the objective lens or by means of the non-linear distribution function.

26 Claims, 11 Drawing Sheets



- The ’990 Patent’s earliest priority date is May 11, 2001.
- The Petition challenges claims 27, 2, 4, 27, 29, and 30 of the ’990 Patent.
- Claim 27, 29, and 30 were newly added during reexamination.
- Claims 2 and 4 were amended to depend from claim 27.

APPLE-1001
(U.S. Patent No. 6,844,990) (“’990 Patent”)

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’990 Patent: Challenged Indep. Claim 27

27. A method for displaying a digital panoramic image, the method comprising:

obtaining a digital panoramic image by projecting a panorama onto an image sensor using a panoramic objective lens, the panoramic objective lens having an image point distribution function that is not linear relative to a field angle of object points of the panorama, the distribution function having a maximum divergence of at least +/−10% compared to a linear distribution function, such that the panoramic image obtained has at least one substantially expanded zone and at least one substantially compressed zone; and

displaying the obtained panoramic image by correcting the non-linearity of the initial image, performed by retrieving image points on the obtained image in a coordinate system of center O' using at least the non-linear distribution function and a size L of the obtained image.

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’990 Patent: Challenged Dependent Claims

2. The method according to claim **[1]** *27*, wherein the objective lens has a non-linear distribution function that is symmetrical relative to the optical axis of the objective lens, the position of an image point relative to the center of the image varying according to the field angle of the corresponding object point.

4. The method according to claim **[1]** *27*, wherein the objective lens expands the edges of the image and compresses the center of the image.

29. The method according to claim 27, wherein the objective lens comprises a set of lenses forming an apodizer.

30. The method according to claim 29, wherein the set of lenses forming an apodizer comprises at least one aspherical lens.

Appendix 3

Overview of the Baker-Shiota Combination

Baker-Shiota Combination

1st Declaration of Dr. Kessler

129. As described in §VIII.A (incorporated here), Baker discloses that its objective lens is used to capture an image in a "warped form" in which the image "warp[ing]" is caused in part by the "magnification" or resolution enhancement along the peripheral field of view. APPLE-1006, 14:18-26. Baker's system "corrects" this warping and displays a "corrected" version of the captured image with the "proper aspect of ratio for the human visual system (i.e., as a perspective corrected view)." APPLE-1006, 14:23-26, 9:5-13.

130. To perform this correction/transformation and "recreate a proper display of the [captured] scene in two dimensions for perspective-correct viewing," Baker's system includes "processor logic in transform processor engine 22" (as shown in Baker's FIG. 1). APPLE-1006, 14:42-47, FIG. 1; *see id.*, 14:47-54. The transform processor "compensates for the distortion or difference in magnification between the central and peripheral areas of the scene caused by the lens by applying appropriate correction criteria to bring the selected portion of the scene into standard viewing format." APPLE-1006, 6:12-16; *see id.*, 6:16-24.

131. For this transformation, Baker contemplates remapping of two-dimensional images from a set of Cartesian coordinates (x,y) as defined within each image sector "unit" (A1, B1, etc.) onto a newly transformed set of coordinates (u,v). APPLE-1006, 14:55-15:6. According to Baker, this remapping is matched to the image's distortion—i.e., to the varying enhancement/magnification resulting from Baker's objective lens. *See* APPLE-1006, 15:14-19 ("The remapping of the pixel location is matched to the differential magnification of the particular periphery-enhancing lens that is used). From these disclosures, a POSITA would have understood that Baker's system corrects or compensates for the distortion introduced into the image by its objective lens (which has a non-linear image distribution).

APPLE-1003, ¶¶129-131

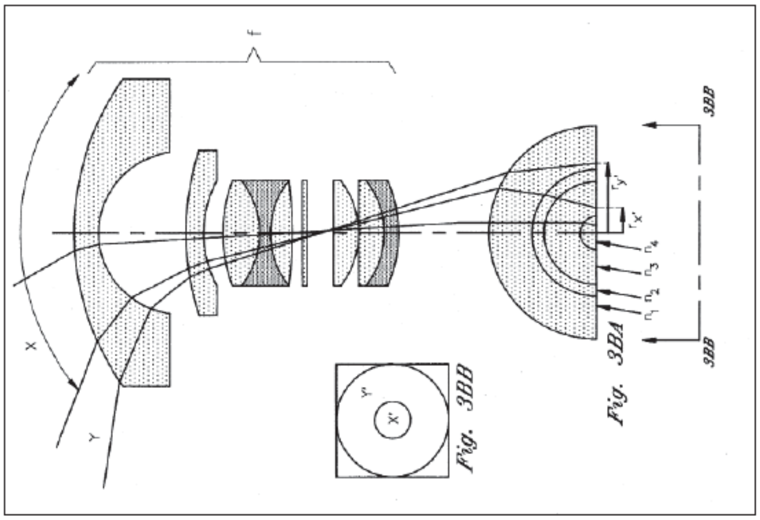
Baker-Shiota Combination

1st Declaration of Dr. Kessler

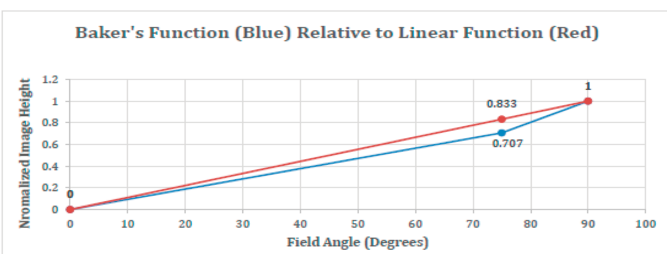
138. In the resulting combination, Baker's non-linear image distribution function would be used—as contemplated by Shiota—to achieve Baker's described "compensation for distortion or difference in magnification between the central and peripheral areas of the scene caused by the lens." *Id.* Given the similar goals and overall functionality of the Shiota and Baker systems (e.g., displaying an image captured using a fish eye lens that compensates for the image's distortion/non-linearity), a POSITA would have had a reasonable expectation of success in so combining these references, and would have reasonably expected to reap the benefits of non-linearity/distortion compensation techniques described in both Shiota and Baker, that result in correction of distortion in the image, which in turn results in an image with "the proper aspect ratio for the human visual system (i.e., as a perspective corrected view)." *Id.*

APPLE-1003, ¶138

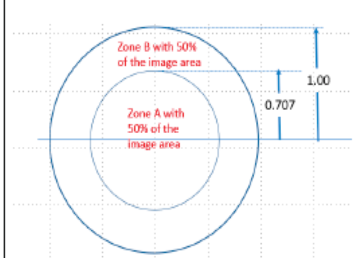
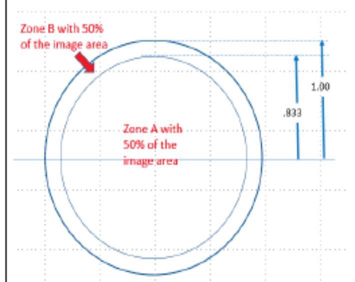
Baker-Shiota Combination



169. Baker's image distribution function can be represented using the following plot showing the normalized image height at various field angles:



1st Declaration of Dr. Kessler

Image zones of Baker's Lens	Image zones of a Linear Lens
	

APPLE-1006, FIGS. 2B, 3B; *see id.*, 13:29-65.

APPLE-1003, ¶¶163-174

FISH.

Baker-Shiota Combination

1st Declaration of Dr. Kessler

202. Specifically, the Baker-Shiota combination would have relied upon Shiota's teachings that describe image correction by applying a correction coefficient (k_2)—which is determined based on a non-linear image distribution function—to the captured image to obtain transformed image points that compensate for the distortion in the captured image. APPLE-1012, [0022]-[0024]. Specifically, the equation for determining the correction coefficient is $k_2 = h/r$, where h represents the lens image distribution function and r is the distance from the origin of an X, Y, Z coordinate system to the projected point on the image plane. APPLE-1012, [0037]-[0042].

203. Again, Patent Owner has acknowledged that these disclosures in Shiota teach correcting the non-linearity of the initial image using a non-linear distribution function. APPLE-1011, 234, 117.

207. Additionally, a POSITA would have understood or found obvious that the size of the image pickup device could be represented using any appropriate units, e.g., pixels, inches, millimeters, etc. Indeed, Baker discloses that its image transformation process includes a "pixel remapping" process (APPLE-1006, 14:64-15:19), and Shiota additionally describes its image transformation process accounts for pixel-based measurements as part of the image transformation process (APPLE-1012, [0022]-[0023], [0025], [0049]). Accordingly, a POSITA would have found it obvious for the size of the image pickup device (and by extension, the size of the image captured by this device) is represented in units of pixels.

APPLE-1003, ¶¶202-207

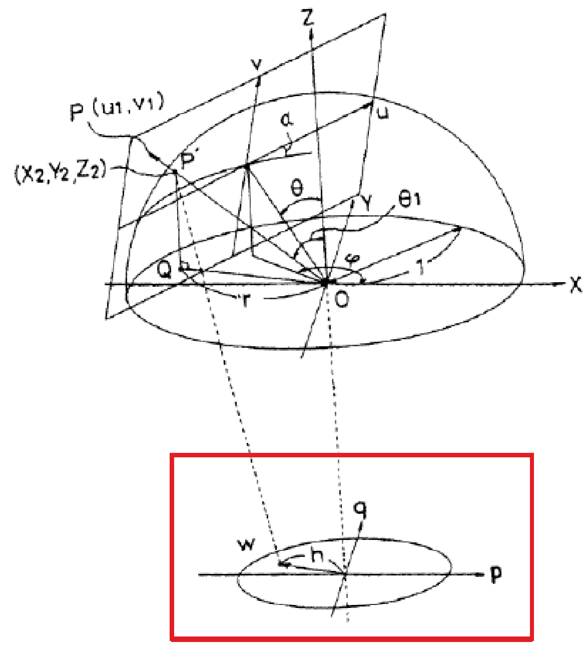
Baker-Shiota Combination

1st Declaration of Dr. Kessler

208. A POSITA would have also understood or found obvious that, in the Baker-Shiota combination, the transformed image points/coordinates are retrieved image points in a coordinate system with center O', consistent with how this feature is described in the '990 Patent. Specifically, in the '990 Patent's specification, the image transformation includes the following steps: (1) the image points of the display window E(i,j) are projected onto a sphere portion HS of center O to obtain points P(px, py, pz), and (2) these points P are then projected onto the image disk using the non-linear distribution function to obtain points p(pu,pv) in a coordinate system of center O' (where O' corresponds to the center of the image disk). *See* APPLE-1001, 12:66-13:24, FIG. 13.

209. Similarly, in Shiota's two-step image transformation process: (1) the points on a plane image corresponding to coordinates of a display monitor are projected on a hemispherical surface to obtains point P' (APPLE-1012, [0022], [0024], [0028])and (2) the point P' is then used to obtain/retrieve second projection coordinates (p, q coordinates) on the image pickup face (which corresponds to the image disk in '990 Patent) by using a non-linear image distribution function (APPLE-1012, [0033], [0035]-[0037], [0040]-[0041]).

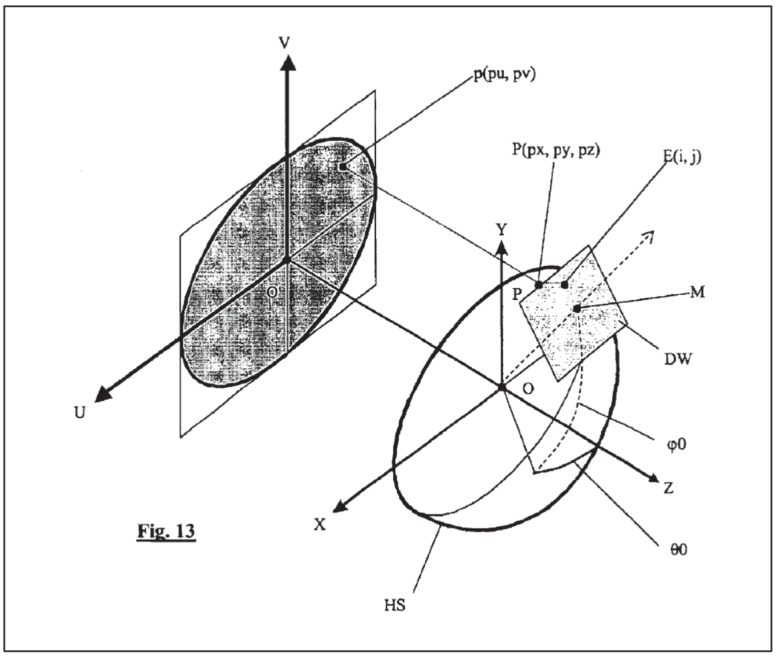
FIG.1



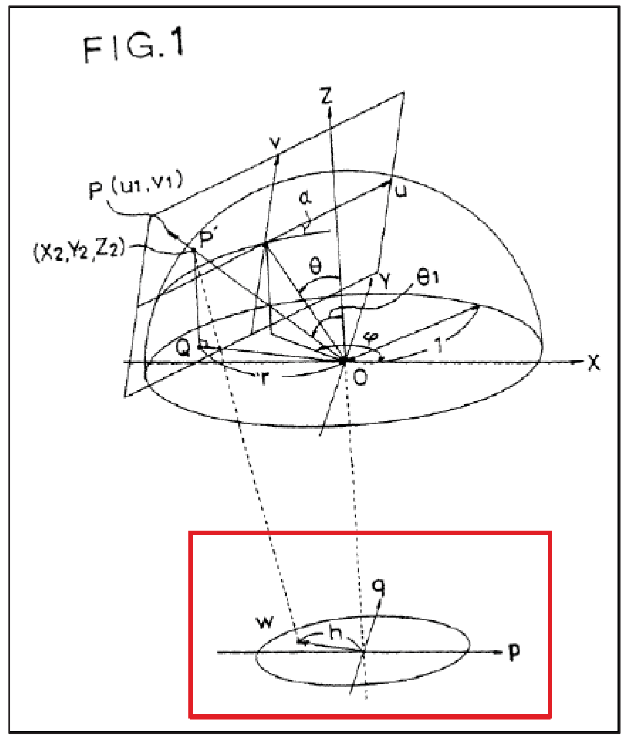
APPLE-1003, ¶¶208-209

Baker-Shiota Combination

’990 Patent, Fig. 13



Shiota, Fig. 1



APPLE-1003, ¶¶208-209

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Shiota – Paragraphs 23, 24, 25, 26

Shiota

[0023] A plane image (fisheye image) obtained through the fisheye lens is expressed by a (p, q) coordinate system as shown in Fig. 1. It is assumed that the (p, q) coordinate system is parallel to the (X, Y) plane and has the origin on the Z axis. In a position on an image pickup face (for example, position of a pixel on a CCD image pickup device), the image circle diameter differs according to the size of the image pickup device and the focal distance of the fisheye lens. Consequently, it is assumed that a fisheye image is projected in a circle of radius 1 of an image of an object positioning at 90 degrees (Z = 0) from the front of the lens. At the time of actually use, magnification adjustment is performed.

[0024] An image is transformed as follows. The projecting position on the image pickup face (p, q coordinates) of a point (u, v coordinates) on a plane image is obtained by arithmetic operation. By referring to luminance information at the point, data of the plane image to be obtained can be generated. Information of the view points (φ, θ, α) and the scale factor (zoom ratio) as the size of the plane image is information inputted by the operator through a keyboard, pointing device, or the like and is obtained and set in advance as data for calculation by a higher-order arithmetic processing unit.

[0025] Necessary parameters are, as shown in Figs. 1 and 2, (X_0, Y_0, Z_0) indicative of the center (origin) of a plane image and change amounts ∂ux, ∂vx, ∂uy, ∂vy, ∂uz, ∂vz in the respective axes of the (X, Y, Z) coordinates when a point is moved in the respective directions on the (u, v) coordinate system by an amount of one pixel (corresponding to one pixel on the monitor screen).

[0026] The parameters can be easily obtained from the information of the angle information (φ, θ, α) of the view point and the magnification of the image.

APPLE-1003, ¶¶191-213; APPLE-1023, ¶¶66-67; APPLE-1012, [0023]-[0026].

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