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(54) Title: METHOD AND DEVICE FOR THE MEASUREMENT OF THE ABDOMINAL SAGITTAL DIAMETER AND/OR OTHER PHYSICAL DIMENSIONS

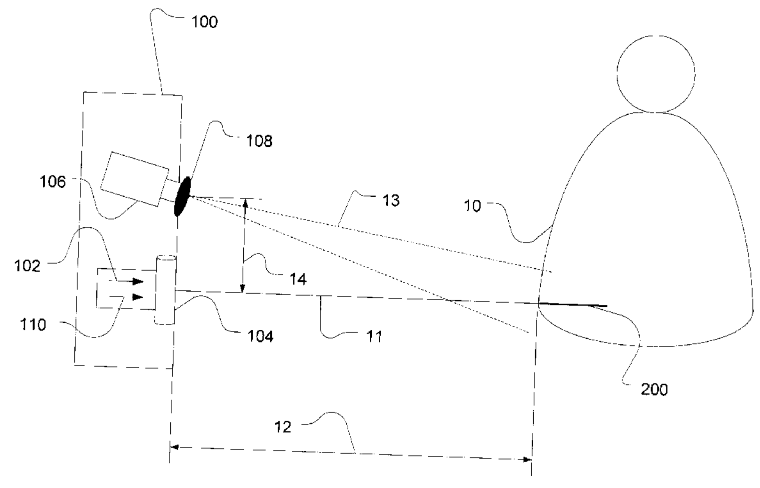

Figure 1

(57) Abstract: A method and its associated device for measuring at least one physical dimension of a target. The method comprises projecting a planar light beam onto the target to produce a reflected light line on the target, acquiring a digital image of the reflected light line on the target, interpolating the reflected light line from the acquired digital image, curve fitting at least part of the interpolated reflected light line to a mathematical model of the target in order to define parameters of the mathematical model, extrapolating the at least one physical dimension of the target from the parameters of the mathematical model and providing the at least one physical dimension of the target.

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METHOD AND DEVICE FOR THE MEASUREMENT OF THE ABDOMINAL SAGITTAL DIAMETER AND/OR OTHER PHYSICAL DIMENSIONS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application claims the benefits of U.S. provisional patent application No. 60/924,996 filed June 7, 2007, which is hereby incorporated by reference.

TECHNICAL FIELD

[0001] The present invention relates to a method and device for the measurement of the physical dimensions of a target. More specifically, the present invention relates to an optical device for the measurement of the abdominal sagittal diameter of a subject.

BACKGROUND

[0002] It is now well recognized that the clustering atherogenic and diabetogenic abnormalities of the metabolic syndrome are highly prevalent in our affluent, sedentary population exposed to a diet of poor nutritional value and of high energy density, leading to the current epidemic of obesity. As a matter of fact, more and more technologies are being developed to ever increasingly spare us from various physical activities in our working and living environments. These resulting sedentary environments can no longer protect us against an energy-dense, refined diet has been adopted by an increasing proportion of our population, leading to the development of a positive energy balance, body weight gain and obesity. Thus, the epidemic proportions reached by obesity worldwide represent a great public health and clinical challenge.

[0003] Although it has been recognized for a long time that excess body weight could cause prejudice to health, physicians have been perplexed by the remarkable heterogeneity of obesity, some very obese patients being fairly healthy whereas some only moderately overweight individuals could show severe metabolic disturbances increasing their risk of type 2 diabetes and cardiovascular disease. In this regard, epidemiological, metabolic and clinical studies have shown that body fat distribution, especially abdominal fat accumulation was the key correlate of metabolic abnormalities that had been in the past associated with excess body weight per se. More than a decade ago, it was suggested, that waist circumference and the sagittal diameter were two good anthropometric correlates of abdominal fat accumulation and related health risk.

[0004] However, it was not until the publication of the recommendations of the National Cholesterol Education Program-Adult Treatment Panel III (NCEP-ATPIII) recognizing abdominal obesity as the most prevalent form of the metabolic syndrome that the importance of assessing abdominal adiposity in clinical practice was emphasized. NCEP-ATPIII guidelines have also emphasized the importance of measuring waist circumference, as a simple approach to identify, in clinical practice, individuals with an excessive accumulation of abdominal fat and at higher risk of showing the features of the metabolic syndrome. On the basis of results from epidemiological, metabolic and clinical studies, it is now well recognized that the metabolic syndrome is a prevalent and powerful risk factor not only for type 2 diabetes but also for cardiovascular disease and that it is frequently accompanied by abdominal obesity. Over the years, evidence that abdominally obese individuals with a preferential excess of visceral (or intra-abdominal) adipose tissue are characterized by the most severe metabolic abnormalities was published.

[0005] Thus, among patients with the features of the metabolic syndrome and at high global risk for cardiovascular disease, it is important in clinical practice to optimally manage the risk associated with this condition by treating not only the individual metabolic abnormalities and risk factors (hypertension, hyperglycemia, the atherogenic dyslipidemia) according to guidelines but also to assess and targeting the culprit cause of the most prevalent form of the metabolic syndrome: abdominal obesity. Unfortunately, the clinician is currently left with little simple tools in his/her arsenal to assess abdominal obesity. Measuring visceral adipose tissue accumulation with a high level of precision requires sophisticated imaging techniques such as magnetic resonance imaging or computed tomography.

[0006] In order to estimate the proportion of abdominal adipose tissue, some anthropometric markers have been proposed. For instance, when measured in a standardized manner, waist circumference is a good anthropometric index of abdominal adiposity. However, few physicians actually measure it in their medical practice because the required procedure is too long and tedious to perform in order to obtain reliable results. Also, the physician has to be in close proximity to the patient for a rather long period of time to perform the measurement.

[0007] In this regard, studies have also shown that another anthropometric parameter, the abdominal sagittal diameter, is even more closely correlated to visceral adipose tissue accumulation than waist circumference. However, the anthropometric device currently used for the measurement of the sagittal diameter is not well suited for the practice of family doctors.

[0008] Accordingly, there is a need for a method and device that allows for quick measurement of the abdominal sagittal diameter and/or circumference of a patient without requiring physical contact.

SUMMARY

[0009] According to an illustrative embodiment of the present invention, there is provided a method for measuring at least one physical dimension of a target, comprising:

projecting a planar light beam onto the target to produce a reflected light line on the target;

acquiring a digital image of the reflected light line on the target;

interpolating the reflected light line from the acquired digital image;

curve fitting at least part of the interpolated reflected light line to a mathematical model of the target in order to define parameters of the mathematical model;

extrapolating the at least one physical dimension of the target from the parameters of the mathematical model; and providing the at least one physical dimension of the target.

[0010] According to another illustrative embodiment of the present invention, the above described method is applied to a human subject, the at least one physical dimension being the sagittal diameter of the human subject. In this regard, the mathematical model includes a first, second and third consecutive segments, the first segment having a first curvature, the second segment being linear and the third segment having a second curvature, the first curvature being greater than the second curvature.

[0011] According to a further illustrative embodiment of the present invention, there is provided a device to be aimed at a target for measuring at least one physical dimension of the target, comprising:

a light source projecting a planar light beam;

a digital camera positioned at an angle with respect to the light source;

a user interface;

a display;

a micro-controller having an associated memory, the micro-controller being operatively connected to the light source, the digital camera, the user interface and the display, wherein the memory comprises a process to be executed by the micro-controller upon activation by the user interface for:

activating the light source projecting a planar light beam onto the target therefore producing a reflected light line on the target;

activating the digital camera therefore acquiring a digital image of the reflected light line on the target;

interpolating the reflected light line from the acquired digital image;

curve fitting at least part of the interpolated reflected light line to a mathematical model of the target in order to define parameters of the mathematical model;

extrapolating the at least one physical dimension of the target from the parameters of the mathematical model; and

outputting to the display the extrapolated at least one physical dimension of the target.

BRIEF DESCRIPTION OF THE FIGURES

[0012] Non-limitative embodiments of the invention will now be described by way of examples only with reference to the accompanying drawings, in which:

[0013] Figure 1 is a schematic view of an abdominal sagittal diameter measuring device being used on a subject;

[0014] Figure 2 is a block diagram of the abdominal sagittal diameter measuring device of Figure 1;

[0015] Figures 3A and 3B is a flow diagram of a process for the computation of physical dimension(s) of a subject;

[0016] Figure 4 is an example of a reflected light line image;

[0017] Figure 5 is a schematic geometric side view of an interpolated reflected light line in world coordinates for the computation of the abdominal sagittal diameter of a subject;

[0018] Figure 6 is a schematic geometric side view of an interpolated reflected light line in world coordinates for the computation of the abdominal circumference of a subject;

[0019] Figure 7 is a flow diagram of a process for improving the computation of the abdominal circumference of a subject according to an illustrative embodiment of the present invention;

[0020] Figure 8 is a schematic geometric front and side view of an interpolated reflected light line in world coordinates for the computation of the abdominal circumference of a subject;

[0021] Figure 9 is a flow diagram of a process for the calibration the abdominal sagittal diameter measuring device of Figure 2; and

[0022] Figure 10 is an example of a calibration plane that may be used with the calibration process of Figure 9.

DETAILED DESCRIPTION

[0023] Generally stated, a method and device according to a non-limitative illustrative embodiment of the present invention provide for the measurement of the abdominal sagittal diameter of a subject using optical profilometry to evaluate abdominal sagittal diameter. Other measurements may be determined as well, for example the circumference of the subject. Furthermore, it is to be understood that the method and device may be adapted to determine the dimensions, for example the width and/or circumference, of various objects depending on the mathematical model used.

[0024] The device for the measurement of the abdominal sagittal diameter may be, for example, in the form of a handheld device which may be used, for example, by a professional health practitioner (physician, nurse, dietetitian, kinesiologist, etc.) in its office or elsewhere. The abdominal sagittal diameter measurement, may then be used by the professional health practitioner in conjunction with other risk assessment markers such as the lipoproteinlipid profile, the oral glucose tolerance test, etc. to assess a patient's global cardiac risk.

[0025] Referring to Figure 1, the abdominal sagittal diameter measuring device (ASDMD) 100 uses a light source 102 passing through cylindrical lens 104 to project a planar light beam 11 onto a subject 10, creating a reflected light line 200. The ASDMD 100 also uses a digital camera 106 to acquire images of the subject as well as of the reflected light line 200. The digital camera 106 may, for example, take grey scale images of a resolution of 640 by 480 pixels. It is to be understood that the digital camera 106 may also take color pictures and/or have a different or adjustable resolution. A bandpass filter 108 of a wavelength similar to the light source 102 may be used with the digital camera 106 so as provide a more accurate image of the reflected light line 200 by filtering out wavelengths not part of the planar light beam 11. The ASDMD 100 then computes, using the acquired digital images, physical dimensions of the subject 10 such as, for example, the abdominal sagittal diameter or circumference. It is to be understood that the cylindrical lens 104 may be omitted if the light source 102 is able to produce a planar light beam 11.

[0026] In an illustrative embodiment, the light source 102 may be, for example, a class II or less (<1 mW, 630 nm to 680 nm) compliant laser. The light source 102 may be activated when the ASDMD 100 is in measurement mode and turned off once the measure is taken, or if the ASDMD 100 is turned off. Measurement is taken in the order of a few seconds or less. If the ASDMD 100 has some difficulty making the measurement, the light source 102 may be turned off after a pre-determined delay, for example 10 seconds.

[0027] In an alternative embodiment, the light source 102 may use a wavelength which is not visible by the human eye, for example near infrared light which suffer less interference from ambient light and provides for a better signal to noise ratio, in which case an optional secondary light source 110, for example a laser pointer, may be used in order to correctly position the light beam 11 onto the subject. It is to be understood that when the light source 102 uses a wavelength which is not visible by the human eye, the digital camera 106 is configured so as to detect this wavelength, for example by using an appropriate filter.

[0028] The digital camera 106 may be set at a fixed angle or it may be adjustable so as to ensure that the reflected light line 200 is positioned within the field of view 13 of the digital camera 106. In an illustrative example, the distance 12 between the ASDMD 100 and the subject 10 may be about 70 centimeters and the distance 14 between the digital camera 106 and the light beam 11 may be about 10 centimeters.

[0029] Referring now to Figure 2, the ASDMD 100, according to an illustrative embodiment of the present invention, further includes a light source driver 103 associated with light source 102, an optional light source driver 111 associated with optional secondary light source 110, a micro-controller 112 with associated memory 114 to process the digital images acquired by the digital camera 106, a user interface 116 to control the functions of the ASDMD 100, a display 118 for displaying measurement results, an optional printer 120 to print measurement results, an optional input/output interface 122 to provide measurement results to a further device or enable a further device to control the ASDMD 100 and a power supply 124. It is to be understood that the display 118, optional printer 120 and optional input/output interface 122 may be used to provide further information such as, for example, date and time, reference number, menu options, etc. and may be used in coordination with the user interface 116.

[0030] The micro-controller 112 and associated memory 114 include a process, which will be further described below, that controls the operations of the ASDMD 100 and computes physical dimensions of the subject 10 such as, for example, the abdominal sagittal diameter or circumference. The results of the computations are then provided to the user of the ASDMD 100 using display 118 and/or optional printer 120. The micro-controller 112 may also be connected to an optional input/output interface 122 through which the computation results, along with other data such as, for example, date and time, reference number, subject identification, practitioner identification, etc., may be provided to another device such as a medical data base. It is to be understood that the input/output interface 122 may be any type of interface such as, for example, an electrical, infrared (IR) or a radio frequency (RF) interface.

[0031] An example of a process 300 that may be executed by the micro-controller 112 for the computation of physical dimensions of the subject 10 is depicted by the flow diagram shown in Figures 3A and 3B. The steps of process 300 are indicated by blocks 302 to 328.

[0032] At block 302, the process 300 starts by acquiring a background image of the target object, for example subject 10 of Figure 1, while light source 102 is turned off, using digital camera 106. For the purpose of the process 300 it will be assumed that the images from the digital camera 106 are in grey scale.

Accordingly, the background image may be expressed as a tri-dimensional matrix I_B (x,y,z_B) x N where z_B is the intensity of the background image for a pixel having coordinates (x,y) and N is the number of pixels in the image. It is to be understood that color images maybe used as well, in which case z_B would be substituted with $R_B G_B B_B$ the red, green and blue components of the background image pixel.

[0033] Then, at block 304, the light source 102 is activated, projecting light beam 11 onto the subject 10 resulting in reflected light line 200.

[0034] At block 306, the digital camera 106 is activated, acquiring an image of the projected light line 200 and of the background, i.e. subject 10. Accordingly, the reflected light line 200 and background image may be expressed as a tri-dimensional matrix I_{L+B} (x,y,z_{L+B}) x N where z_{L+B} is the intensity of the reflected light line 200 and background image for a pixel having coordinates (x,y) and N is the number of pixels in the image.

[0035] At block 308, the light source 102 is turned off.

[0036] Then, at block 310, the image of the projected light line 200 is computed by subtracting the background image matrix I_B acquired at block 302 from the reflected light line 200 and background image matrix I_{L+B} acquired at block 306, resulting in the reflected light line 200 matrix I_L (x,y,z_L) x N where z_L is the intensity of the reflected light line 200 image for a pixel having coordinates (x,y) and N is the number of pixels in the image. More specifically:

$$I_L = I_{L+b} - I_B \,. \qquad \textbf{Equation 1}$$

[0037] Figure 4 shows an example of an image 400 of a projected light line 200 resulting from **Equation 1**.

[0038] It is to be understood that in an alternative embodiment the reflected light line 200 matrix I_L may be obtained using other digital image processing techniques applied directly to an image of the projected light line 200 and of the background, i.e. subject 10, without requiring a previous image of the background.

[0039] Optionally, at block 312, the quality of the reflected light line 200 image may be verified. For example, the process 300 may check for appropriate sharpness, superposition of I_L and I_{L+B}, contrast, discontinuities, etc. If the verification fails, the process 300 goes back to block 302, if the verification passes, it proceeds to block 314.

[0040] Optionally, at block 314, multiple image samples may be acquired in order to provide better accuracy. The number of image samples may be determined empirically or certain conditions may be set, for example the variance of the latest computation of the reflected light line 200 image compared to the average of all computed reflected light lines 200. If another image is to be acquired, then the process 300 proceeds to block 316 where blocks 302 to 312 are repeated and the average of the computed reflected light lines 200 is calculated. If not, the process 300 continues on to block 317.

[0041] At block 317, the process 300 identifies the contour of the reflected light line 200, for example by keeping all pixels for which the intensity z_L is above a certain threshold and discarding the others. In an alternative embodiment, the process 300 may use further image processing techniques to identify the contour of the reflected light line 200, for example eliminating pixels for which the y coordinate is more than a predetermined distance from that of the image center, pixels disconnected from the majority of connected pixels having an intensity z_L above a certain threshold, pixels for which the y coordinate varies more than a given percentage from the number of total pixels in the x coordinate axis, etc. It is to be understood that other image processing techniques may also be used.

[0042] At block 318, the process 300 interpolates, from the reflected light line 200 contour identified at block 317, the reflected light line 200 in the image plane coordinates. The interpolated reflected light line is a matrix $I'_L\ (x,y')$ x M where M is the number of pixels in the interpolated reflected light line and y', for a given x, is computed as follows:

$$y' = \frac{\sum_{y=0}^{N_{y-1}} y \cdot z_{Lxy}}{\sum_{y=0}^{N_{y-1}} z_{Lxy}}. \qquad \textbf{Equation 2}$$

where

z_{Lxy}: is the intensity z_L for a given x and y; and

Ny: is the number of image pixels in the y axis (for example, in a standard image of 640 x 480 pixels Ny will be 480).

[0043] Basically, for a fixed x coordinate there is at most one associated y coordinate value y', which may be in decimal form. It is to be understood that other interpolation methods may be used to determine y', for example fitting a Gaussian equation to each x coordinate and finding its maximum value y'.

[0044] Then, at block 320, the interpolated reflected light line matrix I'_L (x,y') is transferred from the image plane coordinates to the world coordinates. The world coordinates may be planar or, in an alternative embodiment where two or more digital cameras 106 are used, in 3D. The transfer may be effectuated by applying a Homographic transform H to matrix I'_L as follows:

$$I_{WL} = H \cdot I'_L. \qquad \textbf{Equation 3}$$

[0045] The interpolated reflected light line in world coordinates may then be expressed as matrix I_{WL} (x_{WL},y'_{WL}) x M. A calibration process which may be used to determine the Homographic transform H will be detailed further below.

[0046] At block 322, the interpolated reflected light line matrix in world coordinates I_{WL} is segmented, if required. This segmentation depends upon the mathematical model used to model the subject 10 or object being measured.

[0047] Figure 5 shows a mathematical model used in the case where the subject 10 is a human patient. The mathematical model includes a first circle 502, which models the front left-side, a line 504, which models the side, and a second circle 506, which models the back left-side of the patient. In this case, the interpolated reflected light line in world coordinates is composed of segments 402, 403, 404, 405 and 406. Segment 402 may be composed of 15% of the pixels from a first extremity of the interpolated reflected light line in world coordinates, segment 404 may be composed of 30% of the center pixels and segment 406 may be composed of 15% of the pixels from a second extremity. It is to be understood that other mathematical models may be used depending on the shape of the subject 10. It may also be understood that the number of pixels used to define each segment 402, 404 and 406 may vary.

[0048] Then, at block 324, the segments 402, 404 and 406 of the interpolated reflected light line in world coordinates are curve fitted to the mathematical model of the subject 10. For instance, segment 402 is fitted to the first circle 502, segment 404 to line 504 and segment 406 to the second circle 506.

[0049] Thus, the center (x_1,y_1) and the radius r_1 of circle 502 as well as the center (x_2,y_2) and the radius r_2 of circle 506 may be determined using a standard curve fitting process with the pixels comprised in segments 402 and 406, respectively. As for line 504, it may be determined using a best fit process with the pixels comprised in segment 404. The best fit process will result in parameters a, b and c of the following equation:

$$a \cdot x + b \cdot y + c = 0\,. \qquad \textbf{Equation 4}$$

[0050] At block 326, the physical dimensions of the subject 10 are computed.

[0051] First, the width D, or abdominal sagittal diameter in the case of a patient, is computed by extrapolating the blind areas 401 and 407 of Figure 5, which are outside the field of view 13 of the digital camera 106, in order to identify the end points (x_3,y_3) and (x_4,y_4) of the cross section of the subject 10 and projecting those end points onto line 504. The projection of points (x_3,y_3) and (x_4,y_4) onto line 504 results in points (x_5,y_5) and (x_6,y_6), respectively.

[0052] The width D may then be computed as:

$$D = \sqrt{\left((x_6 - x_5)^2 + (y_6 - y_5)^2\right)}\,. \qquad \textbf{Equation 5}$$

[0053] Points (x_5,y_5) and (x_6,y_6) may be computed using **Equations 6 to 13**, which follow.

[0054] First, the unit vectors parallel v and perpendicular $v^{\perp}$ to line 504 are determined using the following equations:

$$v = \frac{[-b,a]}{\sqrt{(a^2+b^2)}}$$; and **Equation 6**

$$v^{\perp} = \frac{[a,b]}{\sqrt{(a^2+b^2)}}.$$ **Equation 7**

[0055] Then, point (x_3,y_3), which is the intersection point between the left side of circle 502 and a line perpendicular to line 504, is computed as:

$$(x_3,y_3) = (x_1,y_1) - r_1 \cdot v.$$ **Equation 8**

[0056] The distance d_1 between (x_3,y_3) and line 504, is then computed as:

$$d_1 = \frac{(a \cdot x_3 + b \cdot y_3 + c)}{\sqrt{(a^2+b^2)}}.$$ **Equation 9**

[0057] Then, point (x_5,y_5), which is the projection of point (x_3,y_3) onto line 504, is computed as:

$$(x_5,y_5) = (x_3,y_3) - d_1 \cdot v^{\perp}.$$ **Equation 10**

[0058] Similarly, point (x_4,y_4), which is the intersection point between the right side of circle 506 and a line perpendicular to line 504, is computed as:

$$(x_4,y_4) = (x_2,y_2) + r_2 \cdot v.$$ **Equation 11**

[0059] The distance d_2 between (x_4,y_4) and line 504, is then computed as:

$$d_2 = \frac{(a \cdot x_4 + b \cdot y_4 + c)}{\sqrt{(a^2+b^2)}}.$$ **Equation 12**

[0060] Finally, point (x_6,y_6), which is the projection of point (x_4,y_4) onto line 504, is computed as:

$$(x_6, y_6) = (x_4, y_4) - d_2 \cdot v^{\perp}.$$ **Equation 13**

[0061] Secondly, referring now to Figure 6, the circumference C is computed by summing the distances between point (x_3,y_3) and a point (x_7,y_7) within segment 402 along segment 401, the distance between point (x_7,y_7) and a point (x_8,y_8) within segment 406 along the interpolated reflected light line in world coordinates, the distance between point (x_8,y_8) and point (x_4,y_4) along segment 407 and distance 408 which is the difference in distances from the center points (x_1,y_1) and (x_2,y_2) of circles 502 and 506, respectively, and line 504, and multiplying the result by two.

[0062] Accordingly, the circumference C may then be computed as:

$$C = 2 \cdot (Arc_1 + Arc_2 + L + (d_2 - d_1)).$$ **Equation 14**

[0063] Arc_1, Arc_2 and L may be computed using **Equations 15 to 21**, which follow.

[0064] First, (x_7,y_7) and (x_8,y_8) are selected as any point within segments 401 and 407, respectively. Points (x_7,y_7) and (x_8,y_8) may be selected relatively near the middle of their respective segments 402 and 406.

[0065] Then, vector w from the center point (x_1,y_1) of circle 502 to point (x_7,y_7) is computed as:

$$w = (x_7, y_7) - (x_1, y_1).$$ **Equation 15**

[0066] The angle θ_1 between vectors w and v is computed as:

$$\theta_1 = \tan^{-1}\left(\frac{w_2}{w_1}\right) - \tan^{-1}\left(\frac{v_2}{v_1}\right).$$ **Equation 16**

[0067] From which the Arc_1, the arc portion of circle 502 between vectors w and v (i.e. points (x_7,y_7) and (x_3,y_3)), is computed as:

$$Arc_1 = r_1 \cdot \theta_1.$$ **Equation 17**

[0068] Similarly, vector z from the center point (x_2,y_2) of circle 506 to point (x_8,y_8) is computed as:

$$z = (x_8, y_8) - (x_2, y_2). \qquad \textbf{Equation 18}$$

[0069] The angle θ_2 between vectors z and v is computed as:

$$\theta_2 = \tan^{-1}\left(\frac{v_2}{v_1}\right) - \tan^{-1}\left(\frac{z_2}{z_1}\right). \qquad \textbf{Equation 19}$$

[0070] From which the Arc_2, the arc portion of circle 506 between vectors z and v (i.e. points (x_8,y_8) and (x_4,y_4)), is computed as:

$$Arc_2 = r_2 \cdot \theta_2. \qquad \textbf{Equation 20}$$

[0071] Finally, distance L, which is the sum of the distances between each pixels between points (x_7,y_7) and (x_8,y_8) along the interpolated reflected light line in world coordinates, is computed as:

$$L = \sum_{i=1}^{M_{7,8}} \sqrt{(x_{i+1} - x_i)^2 + (y_{i+1} - y_i)^2}. \qquad \textbf{Equation 21}$$

where

$M_{7,8}$: is the number of pixels in the interpolated reflected light line in world coordinates between points (x_7,y_7) and (x_8,y_8); and

(x_i,y_i): for i = 1 to $M_{7,8}$ are the pixels composing the interpolated reflected light line in world coordinates between points (x_7,y_7) and (x_8,y_8).

[0072] Finally, at block 328, the width D, or abdominal sagittal diameter, and/or circumference C of the subject 10 are provided.

[0073] The measure of the circumference of the subject 10 described at block 326 of process 300 may be improved using, for example, process 700 which is depicted by the flow diagram shown in Figure 7. The steps of process 700 are indicated by blocks 702 to 716.

[0074] At block 702, the process 700 starts by repeating blocks 302 to 322 of process 300 (see Figures 3A and 3B) on an alternative view of the subject 10. Figure 8 shows a second field of view 13', acquired with digital camera 106' and associated bandpass filter 108', which is generally at a 90° angle from the initial field of view 13.

[0075] Then, at block 704, the center point (x'_1,y'_1) and the radius r'_1 of circle 502' as well as the equation of line 504' are determined from the pixels comprised in segments 402' and 404', respectively.

[0076] Center point (x'_1,y'_1) and radius r'_1 of circle 502' are determined using a standard curve fitting process with the pixels comprised in segment 402', which may be composed of 15% of the pixels from a first extremity of the interpolated reflected light line in world coordinates according to field of view 13'.

[0077] As for the equation of line 504', it may be determined using a best fit process with the pixels comprised in segment 404', which may be composed of 30% of the center pixels of the interpolated reflected light line in world coordinates according to field of view 13'.

[0078] At block 706, the coordinate system of the alternative view is adjusted such that the center point (x'_1,y'_1) and the radius r'_1 of circle 502' match the center point (x_1,y_1) and the radius r_1 of circle 502.

[0079] At block 708, point (x'_3,y'_3) is determined by projecting point (x'_1,y'_1) perpendicularly onto line 504'.

[0080] Following which, at block 710, point (x'_7,y'_7) is determined by projecting point (x'_1,y'_1) onto circle 502' at angle θ_1.

[0081] Then, at block 712, Arc_1 in **Equation 14** is replaced by the sum of the distances between each pixels between points (x'_3,y'_3) and (x'_7,y'_7) along the interpolated reflected light line in world coordinates according to field of view 13', which is computed as:

$$Arc_1 = \sum_{i=1}^{M_{3,7}} \sqrt{(x'_{i+1} - x'_i)^2 + (y'_{i+1} - y'_i)^2} \, . \qquad \textbf{Equation 21}$$

where

$M_{3,7}$ is the number of pixels in the interpolated reflected light line in world coordinates between points (x'_3,y'_3) and (x'_7,y'_7); and

(x'_i,y'_i) for i = 1 to $M_{3,7}$ are the pixels composing the interpolated reflected light line in world coordinates between points (x'_3,y'_3) and (x'_7,y'_7).

[0082] At block 714, the process 700 verifies if there is another view, i.e. another digital camera or field of view for which the image has not been treated yet.

[0083] If there is another view, then the process 700 proceeds to block 716 where blocks 702 to 712 are repeated for the new view. It is to be understood that the operations of blocks 702 to 712 may vary depending on the mathematical model representing the part of the subject 10 in the new field of view. For example, a field of view opposed to that of field of view 13' may be used to compute Arc_1 similarly to above with a circle similar to circle 506 and be replaced in **Equation 14**. It is to be understood that the number of views may vary according to the complexity of the mathematical model used to model the subject 10.

Calibration

[0084] Referring to Figure 9, there is shown flow diagram of a calibration process 900 for the ASDMD 100 which may be used to determine the Homographic transform H which is used at block 320 of process 300 (see Figures 3A and3B to transfer the interpolated reflected light line matrix I'_L from the image plane coordinates to the world coordinates. The steps of process 900 are indicated by blocks 902 to 920.

[0085] At block 902, the process 900 starts by activating the light source 102 and projecting the planar light beam 11 onto a calibration plane instead of the subject 10, the calibration plane being positioned generally at the same distance the subject 10 would be placed. Figure 10 shows an example of a calibration plane 1000 that may be used with the calibration process 900. The calibration plane

1000 comprises a number of ellipsoids 1002, 1004 having respective center points (x_{2Ci},y_{2Ci}) and (x_{4Cj},y_{4Cj}) with associated radiuses r_{2Ci} and r_{4Cj}, for i = 1 to N_{2C} and j = 1 to N_{4C}, where N_{2C} and N_{4C} are the number of ellipsoids 1002 and 1004, respectively. It is to be understood that the ellipsoids may be of more than two different sizes.

[0086] Then, at block 904, the planar light beam 11 is positioned such that it is generally in the same plane as the calibration plane 1000.

[0087] At block 906, the light source 102 is turned off.

[0088] At block 908, the digital camera 106 is activated, taking a picture of the calibration plane 1000.

[0089] Optionally, at block 910, the quality of the calibration plane 1000 image is verified. For example, the process 900 may check for appropriate sharpness, contrast, etc. If the verification fails, the process 900 goes back to block 902, if the verification passes, it proceeds to block 912.

[0090] Optionally, at block 912, multiple image samples may be acquired in order to provide better accuracy. The number of image samples may be determined empirically or certain conditions may be set. If another image sample is to be acquired, then the process 900 proceeds to block 914 where blocks 908 to 910 are repeated and the average image is calculated. If not, the process 900 continues on to block 916.

[0091] At block 916, the process 900 extrapolates the various ellipsoids 1002, 1004 in the image plane and curve fits them to the mathematical model an ellipsoid in order to compute center points (x'_{2Ci},y'_{2Ci}) and (x'_{4Cj},y'_{4Cj}) with associated radiuses r'_{2Ci} and r'_{4Cj} in the image plane coordinates.

[0092] Then, at block 918, the orientation of the image plane is determined by comparing the coordinates of the ellipsoids 1002, 1004 in the image plane with those in the calibration plane 1000.

[0093] Finally, at block 920, the Homographic transform H is computed using the center points (x'_{2Ci},y'_{2Ci}) and (x'_{4Cj},y'_{4Cj}) with associated radiuses r'_{2Ci} and r'_{4Cj} of each ellipsoid 1002, 1004 in the image plane coordinates and their corresponding center points (x_{2Ci},y_{2Ci}) and (x_{4Cj},y_{4Cj}) with associated radiuses r_{2Ci} and r_{4Cj} in the calibration plane 1000. As the planar light beam 11 is positioned such that it is generally in the same plane as the calibration plane 1000, the application of the resulting Homographic transform H to an object transfers that object's coordinates from the image plane coordinates into world coordinates.

[0094] It is to be understood that although references are made to the measurement of the abdominal sagittal diameter and circumference of a subject, in alternative embodiments the subject may be replaced by an object, for example a wood log, for which the physical dimensions are desired even though the object is not in full view. It is also to be understood that the mathematical equations used to model the object being measured will vary depending on the geometry of the object but that the general steps of the various processes disclosed herein will be similar.

[0095] Although the present invention has been described by way of particular embodiments and examples thereof, it should be noted that it will be apparent to persons skilled in the art that modifications may be applied to the present particular embodiment without departing from the scope of the present invention.

WHAT IS CLAIMED IS:

1. A method for measuring at least one physical dimension of a target, comprising:

projecting a planar light beam onto the target to produce a reflected light line on the target;

acquiring a digital image of the reflected light line on the target;

interpolating the reflected light line from the acquired digital image;

curve fitting at least part of the interpolated reflected light line to a mathematical model of the target in order to define parameters of the mathematical model;

extrapolating the at least one physical dimension of the target from the parameters of the mathematical model; and

providing the at least one physical dimension of the target.

2. A method according to claim 1, further comprising acquiring a first digital image of the target previous to projecting the planar light beam onto the target and computing a result image of the reflected light line by subtracting the first digital image from the acquired digital image.

3. A method according to claim 1, wherein interpolating the reflected light line from its digital image includes identifying a contour of the reflected light line from the acquired digital image and interpolating the reflected light line from the identified contour in a first coordinates system.

4. A method according to claim 3, further comprising transferring the interpolated reflected light line from the first coordinates system to a second coordinates system before curve fitting at least part of the interpolated reflected light line to the mathematical model of the target.

5. A method according to claim 4, wherein the interpolated reflected light line from the first coordinates system is transferred to second coordinates system using a homographic transform.

6. A method according to claim 1, wherein the target is a human subject.

7. A method according to claim 6, wherein the at least one physical dimension is the sagittal diameter of the human subject.

8. A method according to claim 7, wherein the mathematical model includes two partially overlapping circles of different dimensions.

9. A method according to claim 7, wherein the mathematical model includes a first, second and third consecutive segments, the first segment having a first curvature, the second segment being linear and the third segment having a second curvature, wherein the first curvature is greater than the second curvature.

10. A method according to claim 9, wherein curve fitting at least part of the interpolated reflected light line to the mathematical model includes fitting 15% of the pixels of a first extremity of the interpolated reflected light line to the first segment, 30% of the center pixels of the interpolated reflected light line to the second segment and 15% of the pixels of a second extremity of the interpolated reflected light line to the third segment.

11. A method according to claim 1, wherein acquiring a digital image of the reflected light line on the target includes acquiring a plurality of digital images from different views.

12. A method according to claim 1, wherein acquiring a digital image of the reflected light line on the target includes acquiring a plurality of digital images and averaging the acquired digital images.

13. A method for measuring of the physical dimensions of a target, comprising:

acquiring a first digital image of the target;

projecting a planar light beam onto the target;

acquiring a second digital image of the target including a reflection of the projected light line;

subtracting the first digital image from the second digital image in order to obtain a digital image of the reflected light line;

identifying the contour of the reflected light line from its digital image;

interpolating the reflected light line from its contour in a first coordinates system;

transferring the interpolated reflected light line from the first coordinates system to a second coordinates system;

curve fitting at least part of the interpolated reflected light line to a mathematical model of the target in order to define parameters of the mathematical model;

extrapolating the at least one physical dimension of the target from the parameters of the mathematical model; and

providing the at least one physical dimension of the target.

14. A method according to claim 13, wherein the target is a human subject.

15. A method according to claim 14, wherein the at least one physical dimension is the sagittal diameter of the human subject.

16. A method according to claim 15, wherein the mathematical model includes two partially overlapping circles of different dimensions.

17. A method according to claim 15, wherein the mathematical model includes a first, second and third consecutive segments, the first segment having a first curvature, the second segment being linear and the third segment having a second curvature, wherein the first curvature is greater than the second curvature.

18. A method according to claim 17, wherein curve fitting at least part of the interpolated reflected light line to the mathematical model includes fitting 15% of the pixels of a first extremity of the interpolated reflected light line to the first segment, 30% of the center pixels of the interpolated reflected light

line to the second segment and 15% of the pixels of a second extremity of the interpolated reflected light line to the third segment.

19. A device to be aimed at a target for measuring at least one physical dimension of the target, comprising:

a light source projecting a planar light beam;

a digital camera positioned at an angle with respect to the light source;

a user interface;

a display;

a micro-controller having an associated memory, the micro-controller being operatively connected to the light source, the digital camera, the user interface and the display, wherein the memory comprises a process to be executed by the micro-controller upon activation by the user interface for:

activating the light source projecting a planar light beam onto the target therefore producing a reflected light line on the target;

activating the digital camera therefore acquiring a digital image of the reflected light line on the target;

interpolating the reflected light line from the acquired digital image;

curve fitting at least part of the interpolated reflected light line to a mathematical model of the target in order to define parameters of the mathematical model;

extrapolating the at least one physical dimension of the target from the parameters of the mathematical model; and

outputting to the display the extrapolated at least one physical dimension of the target.

20. A device according to claim 19, wherein the target is a human subject.

21. A device according to claim 20, wherein the at least one physical dimension is the sagittal diameter of the human subject.

22. A device according to claim 21, wherein the mathematical model includes two partially overlapping circles of different dimensions.

23. A device according to claim 21, wherein the mathematical model includes a first, second and third consecutive segments, the first segment having a first curvature, the second segment being linear and the third segment having a second curvature, wherein the first curvature is greater than the second curvature.

24. A device according to claim 23, wherein curve fitting at least part of the interpolated reflected light line to the mathematical model includes fitting 15% of the pixels of a first extremity of the interpolated reflected light line to the first segment, 30% of the center pixels of the interpolated reflected light line to the second segment and 15% of the pixels of a second extremity of the interpolated reflected light line to the third segment.

25. A device according to claim 19, wherein the light source includes a Class II or less compliant laser and a cylindrical lens.

26. A device according to claim 19, wherein the light source is of a wavelength that is not visible to the human eye.

27. A device according to claim 26, wherein the wavelength is near the infrared.

28. A device according to claim 26, further comprising a secondary light source in a wavelength that is visible to the human eye for positioning the planar light beam on the target.

29. A device according to claim 28, wherein the secondary light source is a laser pointer.

30. A device according to claim 19, further comprising a bandpass filter operatively connected to the digital camera, the bandpass filter being of a wavelength similar to the wavelength of the light source.

31. A device according to claim 19, wherein the angle between the digital camera and the light source is adjustable.

32. A device according to claim 19, further comprising a printer operatively connected to the micro-controller for printing the at least one physical dimension of the target.

33. A device according to claim 19, further comprising an input/output interface operatively connected to the micro-controller.

34. A device according to claim 33, wherein the input/output interface is selected from the group consisting of an electrical interface, an infrared interface and a radio frequency interface.

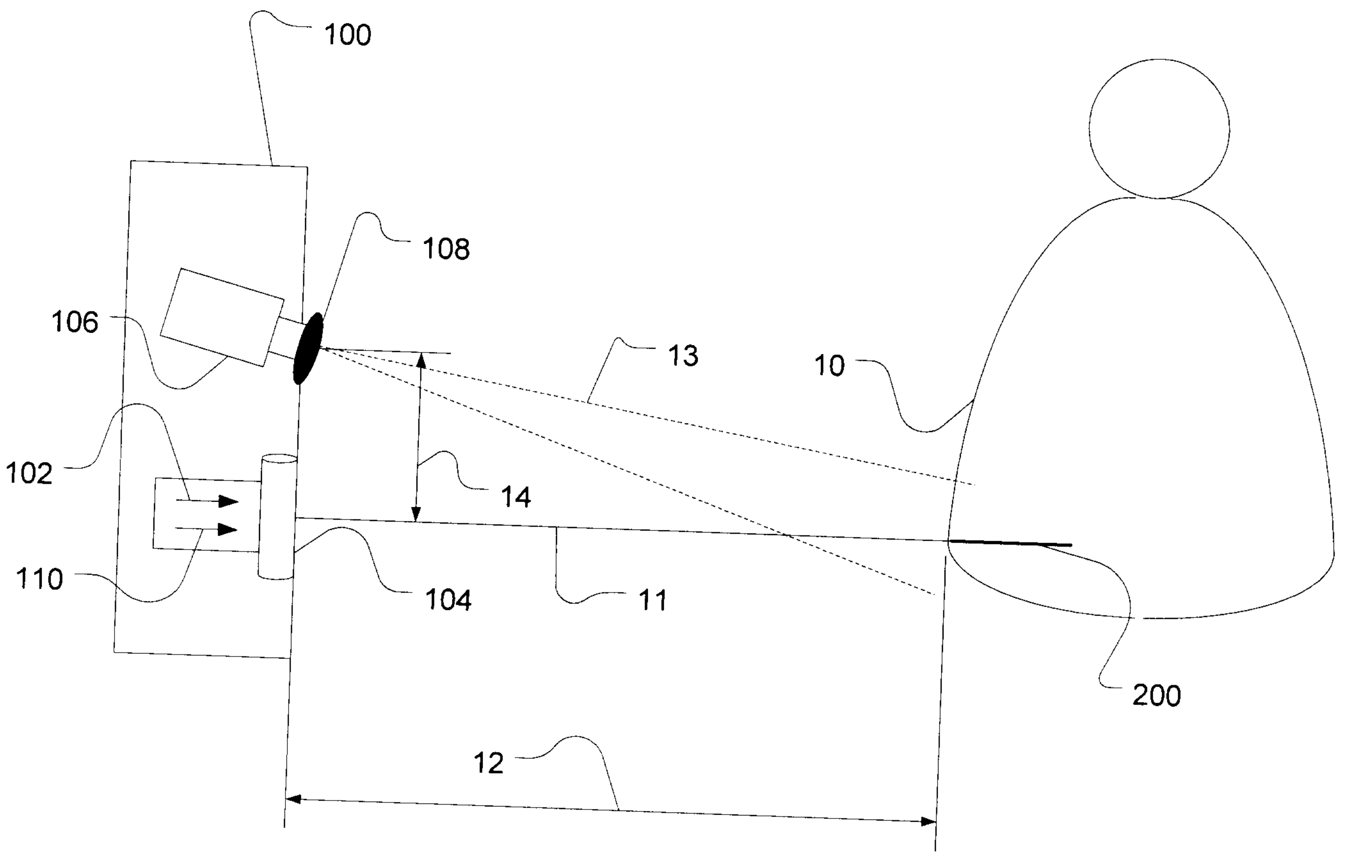

Figure 1

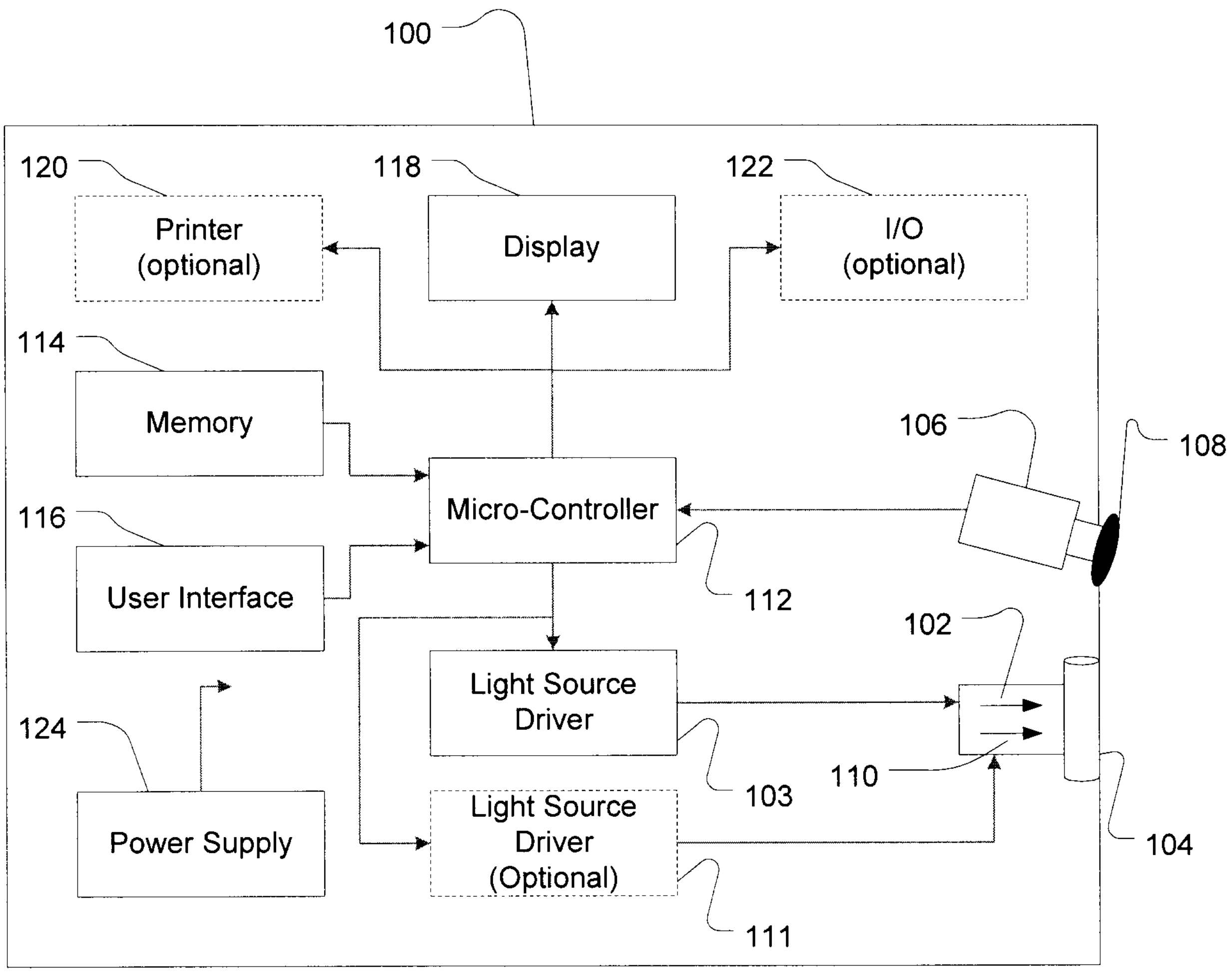
100
120
Printer
(optional)
118
Display
122
I/O
(optional)
114
Memory
106
108
116
Micro-Controller
User Interface
112
102
Light Source
Driver
124
110
103
104
Power Supply
Light Source
Driver
(Optional)
111

Figure 2

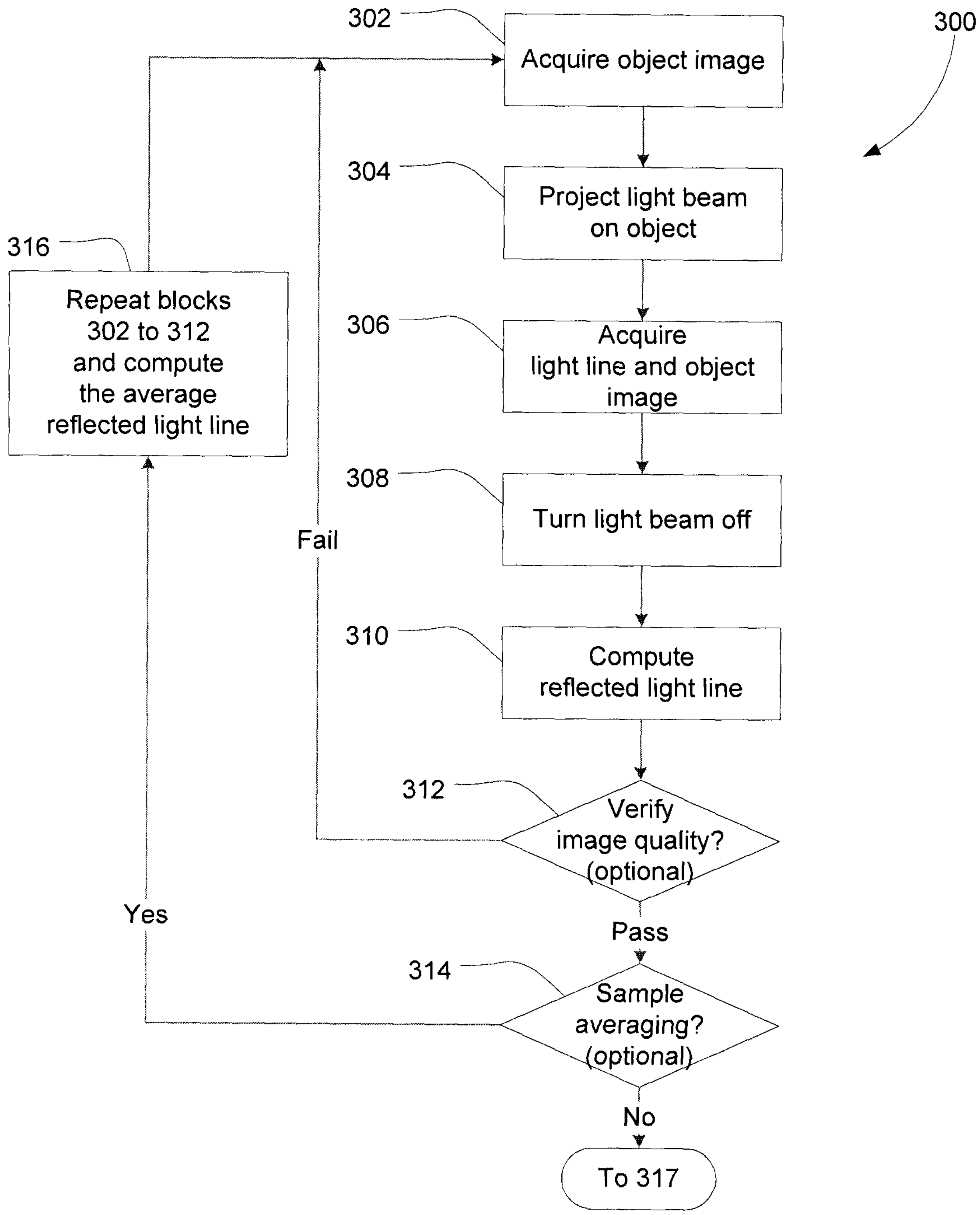
300
302
Acquire object image
304
Project light beam on object
306
Acquire light line and object image
308
Turn light beam off
310
Compute reflected light line
312
Verify image quality? (optional)
Fail
Pass
314
Sample averaging? (optional)
Yes
No
To 317
316
Repeat blocks 302 to 312 and compute the average reflected light line

Figure 3A

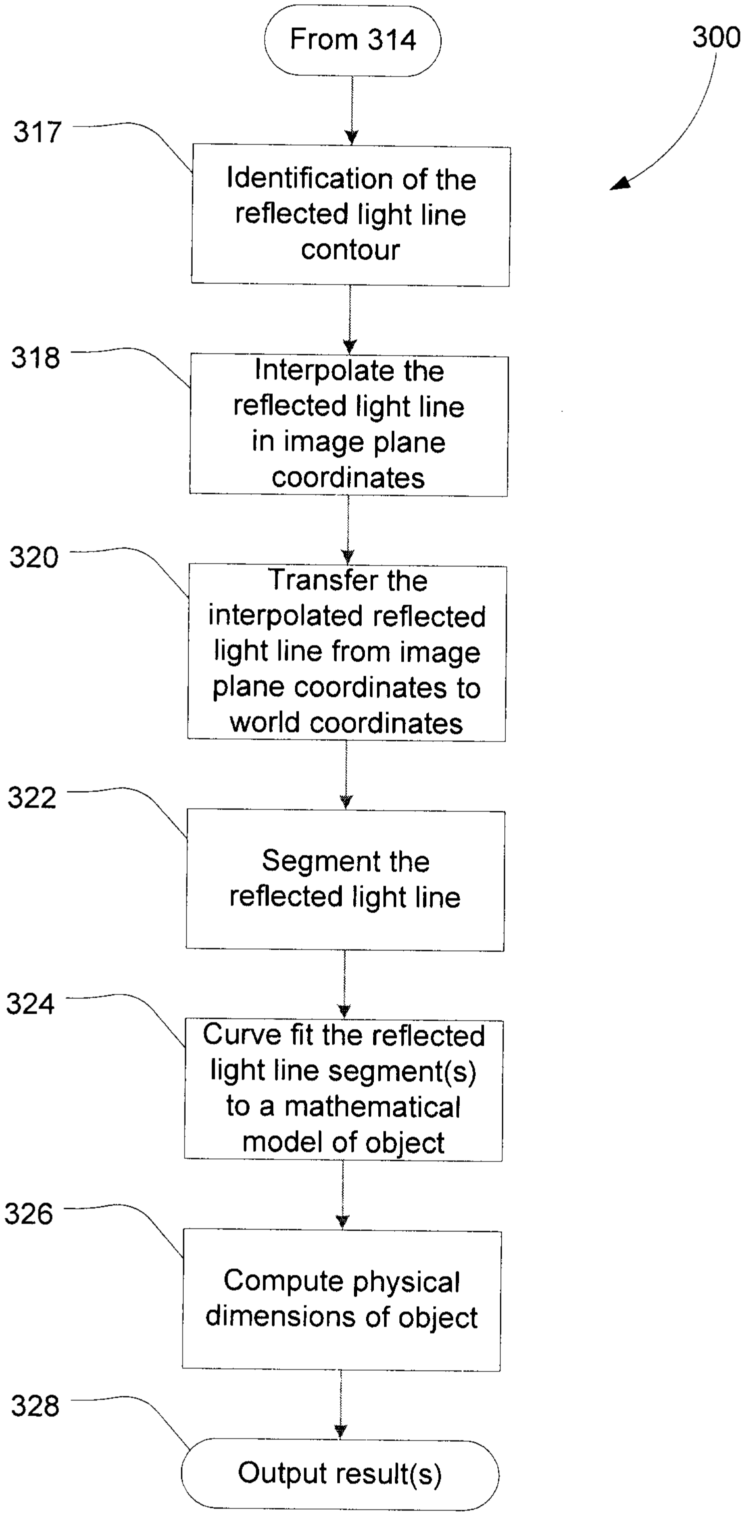
From 314
300
317
Identification of the reflected light line contour
318
Interpolate the reflected light line in image plane coordinates
320
Transfer the interpolated reflected light line from image plane coordinates to world coordinates
322
Segment the reflected light line
324
Curve fit the reflected light line segment(s) to a mathematical model of object
326
Compute physical dimensions of object
328
Output result(s)

Figure 3B

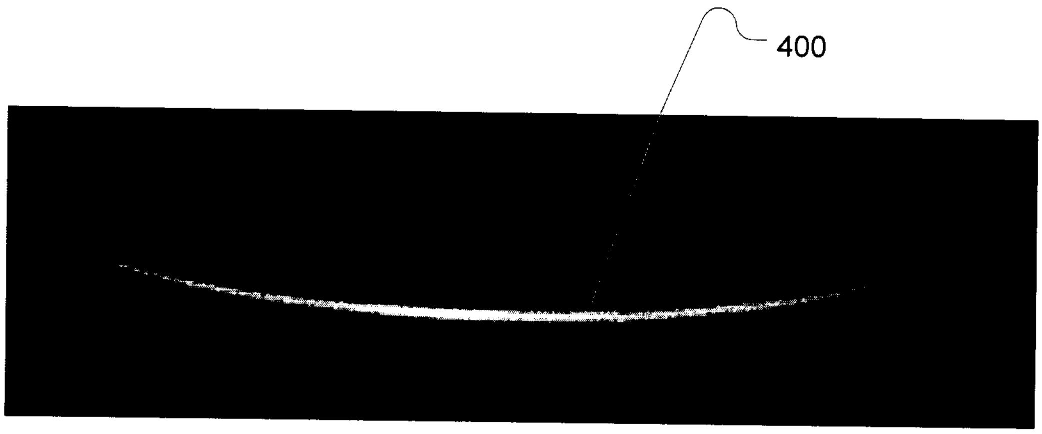

Figure 4

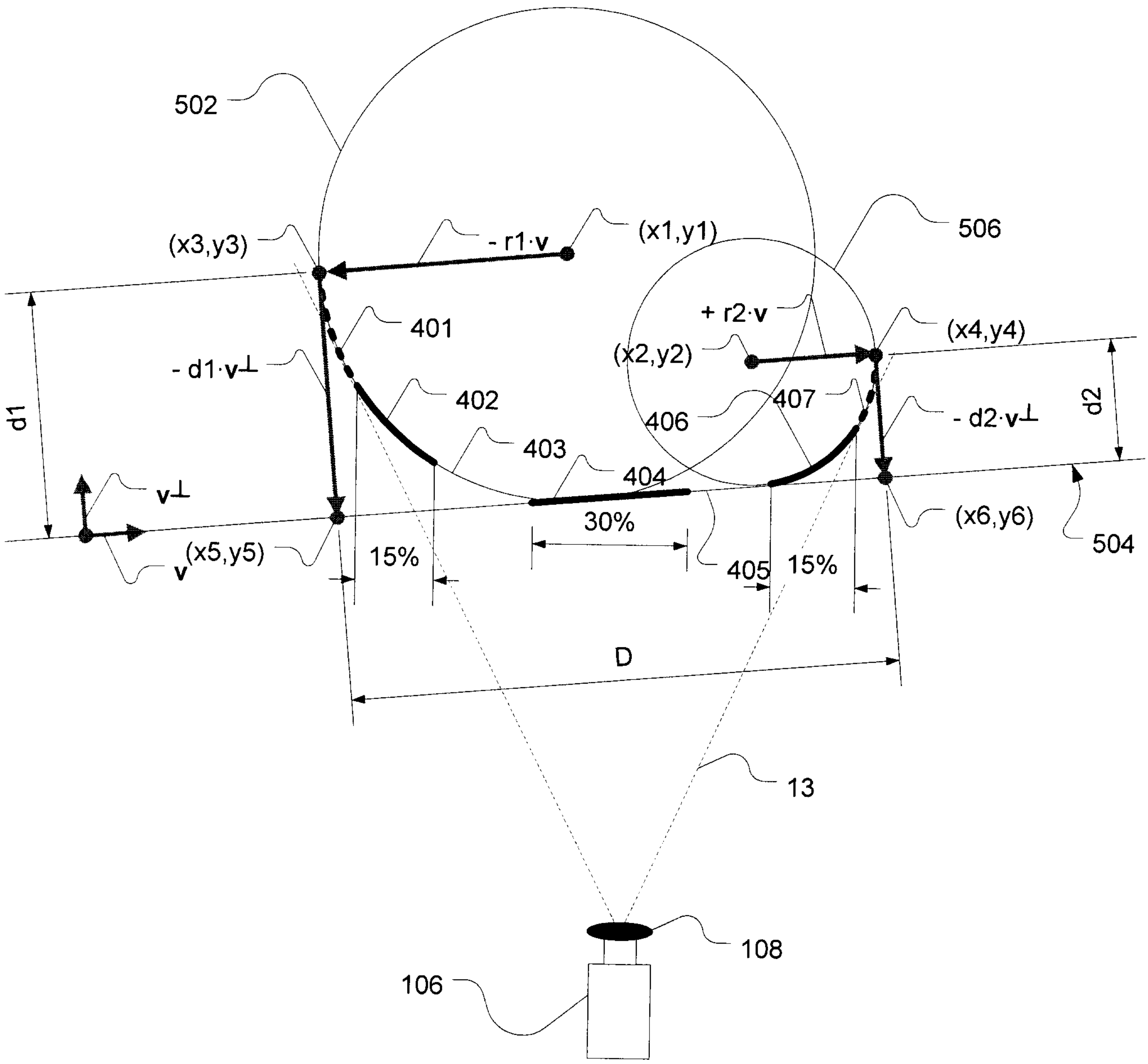
502
(x3,y3)
- r1·v
(x1,y1)
506
401
+ r2·v
(x4,y4)
(x2,y2)
- d1·v⊥
d1
402
407
406
- d2·v⊥
d2
403
404
v⊥
30%
(x6,y6)
504
v
(x5,y5)
15%
405
15%
D
13
108
106

Figure 5

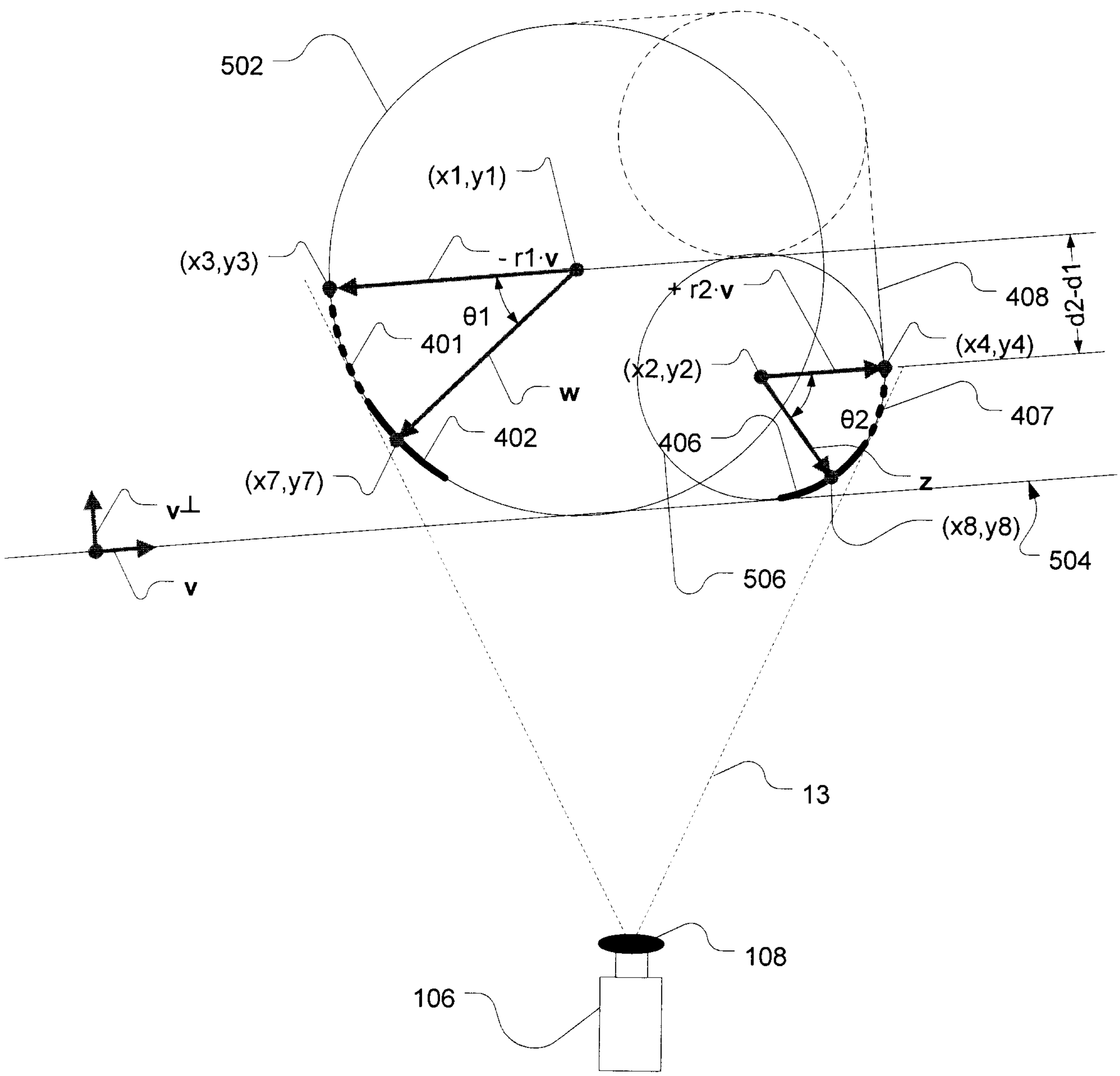
502
(x1,y1)
(x3,y3)
- r1·v
θ1
401
w
402
(x7,y7)
+ r2·v
408
d2-d1
(x4,y4)
(x2,y2)
θ2
407
406
z
(x8,y8)
504
v⊥
v
506
13
108
106

Figure 6

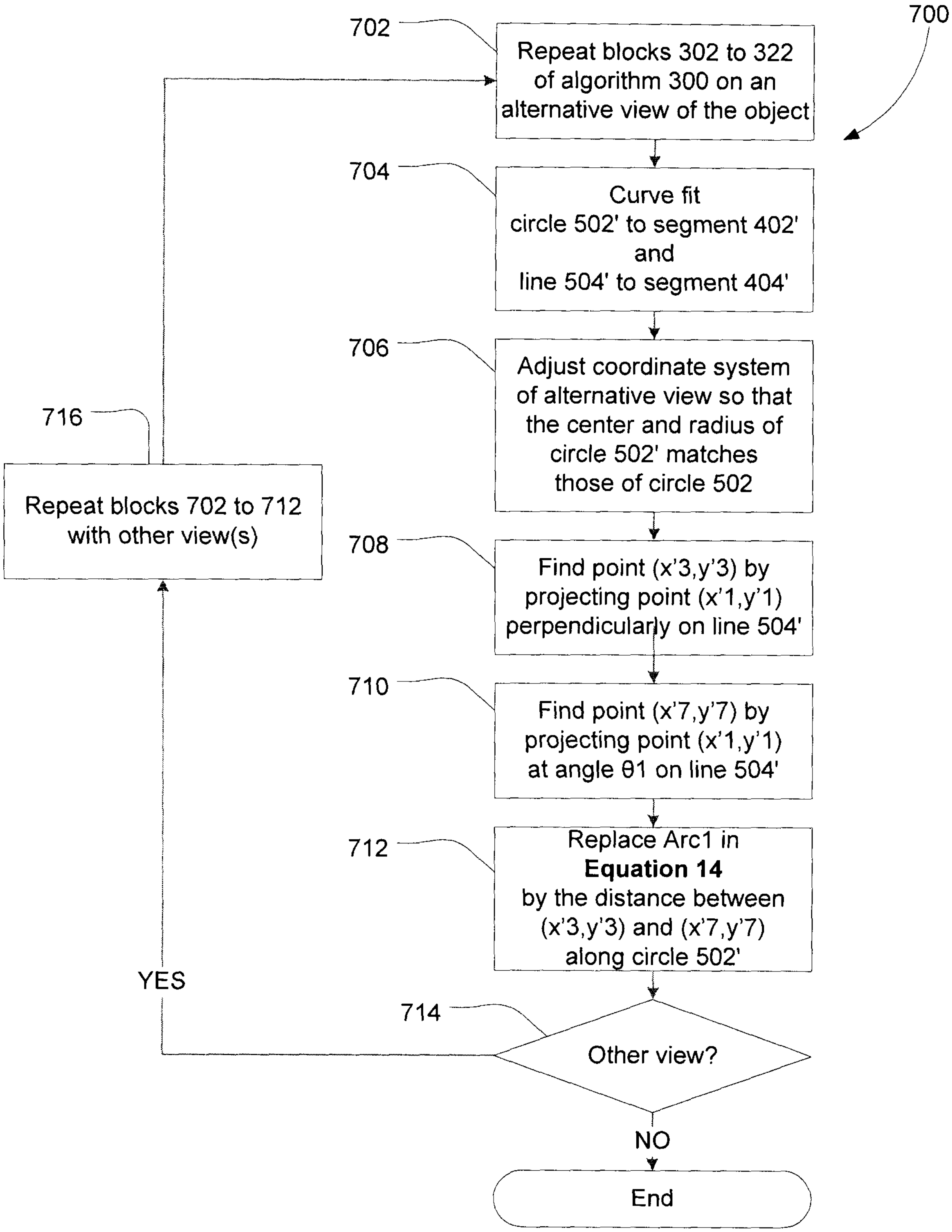
700
702
Repeat blocks 302 to 322 of algorithm 300 on an alternative view of the object
704
Curve fit circle 502' to segment 402' and line 504' to segment 404'
706
Adjust coordinate system of alternative view so that the center and radius of circle 502' matches those of circle 502
708
Find point (x'3,y'3) by projecting point (x'1,y'1) perpendicularly on line 504'
710
Find point (x'7,y'7) by projecting point (x'1,y'1) at angle θ1 on line 504'
712
Replace Arc1 in Equation 14 by the distance between (x'3,y'3) and (x'7,y'7) along circle 502'
714
Other view?
YES
NO
End
716
Repeat blocks 702 to 712 with other view(s)

Figure 7

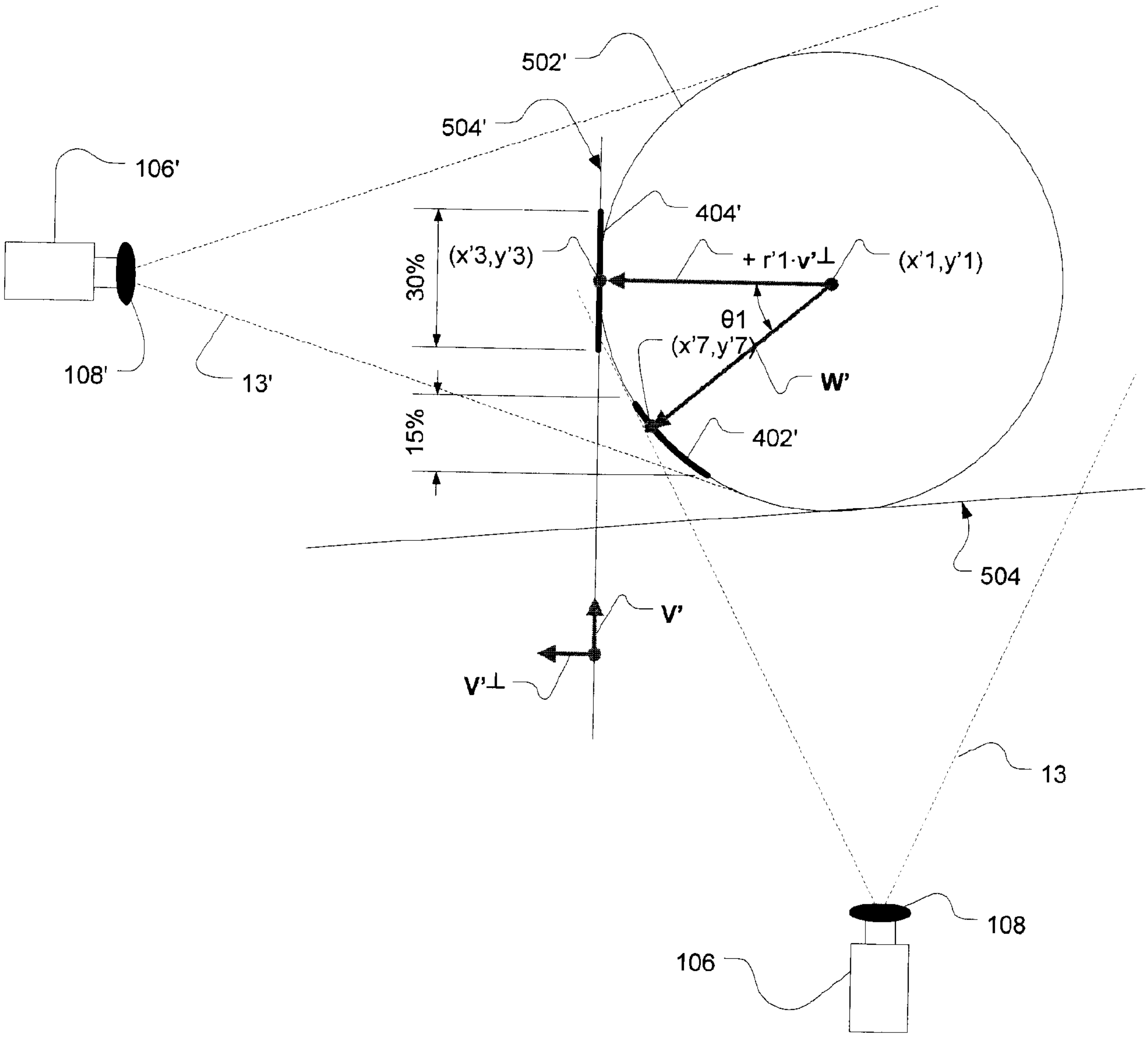
502'
504'
106'
404'
30%
(x'3,y'3)
+ r'1·v'⊥
(x'1,y'1)
θ1
(x'7,y'7)
W'
108'
13'
15%
402'
504
V'
V'⊥
13
108
106

Figure 8

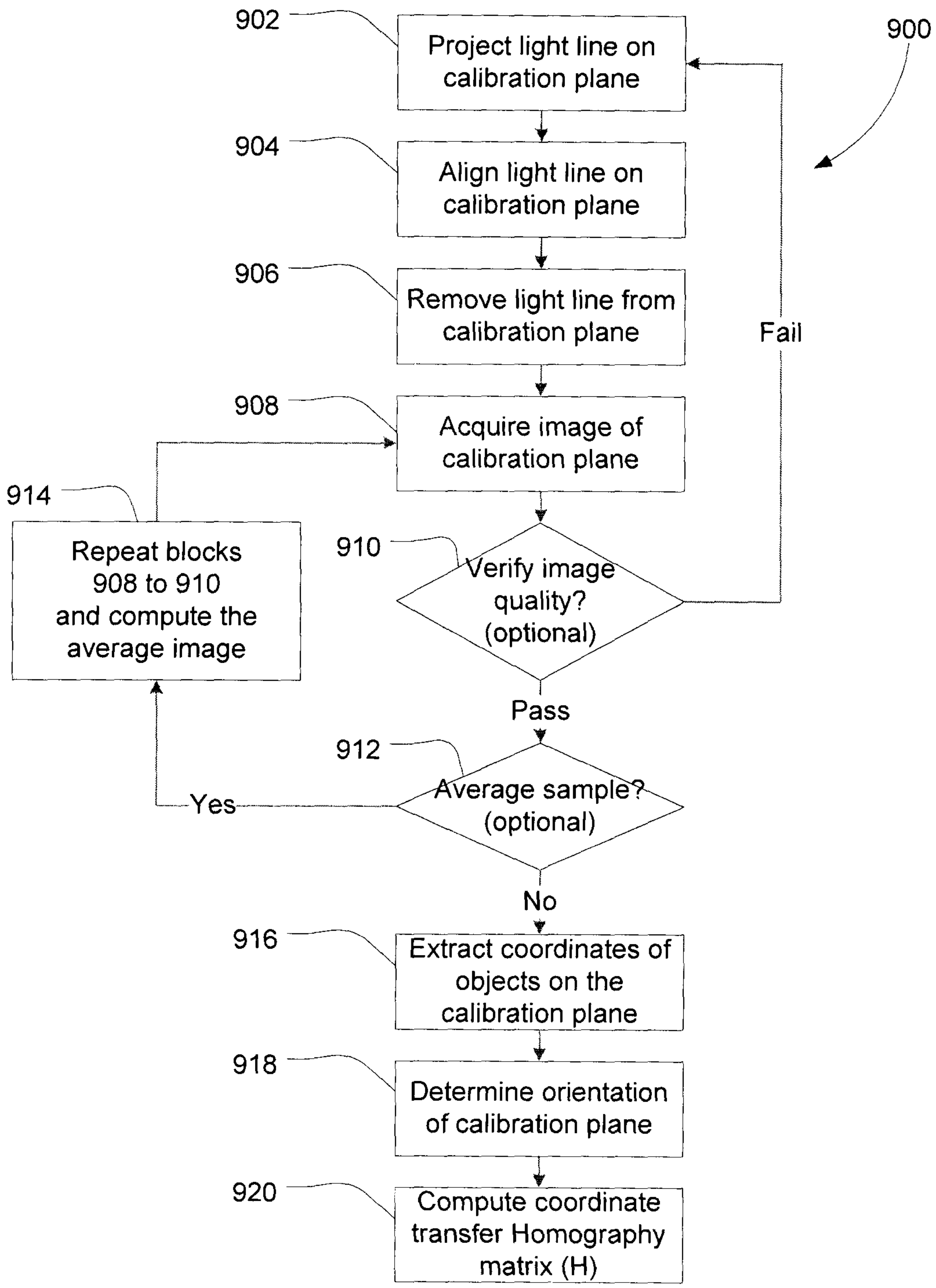
900
902
Project light line on calibration plane
904
Align light line on calibration plane
906
Remove light line from calibration plane
908
Acquire image of calibration plane
910
Verify image quality? (optional)
Fail
Pass
912
Average sample? (optional)
Yes
914
Repeat blocks 908 to 910 and compute the average image
No
916
Extract coordinates of objects on the calibration plane
918
Determine orientation of calibration plane
920
Compute coordinate transfer Homography matrix (H)

Figure 9

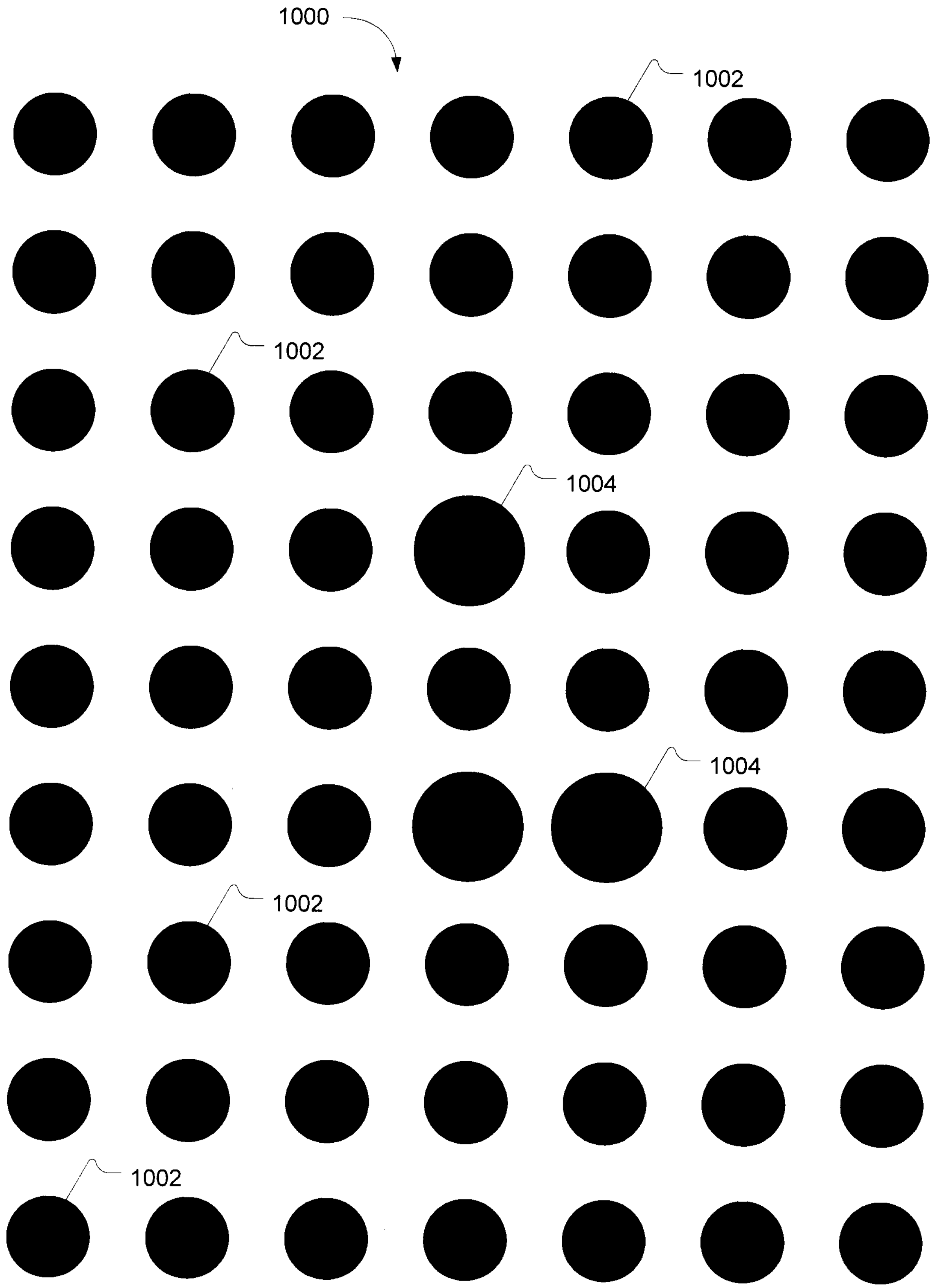

Figure 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2008/001105

A. CLASSIFICATION OF SUBJECT MATTER
IPC: ***G01B 11/00*** (2006.01) , ***A61B 5/107*** (2006.01) , ***G01B 11/25*** (2006.01) , *G01B 11/255* (2006.01)
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC (2006.01): G01B*; A61B*
USCL: 356/376; 356/*;250/*

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

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
Canadian Patent Database, Delphion, USPTO, Espacenet
keywords: measuring dimension, target, light, image, line, interpolat*, extrapolat*, curve fitting, mathematical model, subtracting images, contour

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US5753931 A (BORCHERS E.B. et al.)19 May 1998 (19-05-1998) *see whole document*	1-3, 6-9, 11, 12-17, 19, 20-23, 25, 30-34
X	US7069153 B2 (JOHNSON K. C.) 27 June 2006 (27-06-2006)*Fig. 1, claim 1*	1, 3, 6, 11, 19, 20, 25-29, 31-34
Y	US6064759 A (BUCKLEY B. S. et al.) 16 May 2000 (16-05-2000) *Fig. 1, col. 5, line55- col. 7, line 61*	1, 3, 4, 5, 11,12, 19, 25, 31-34
Y	US6618155 B2 (METCALFE L. et al) 9 September 2003 (09-09-2003)*Fig. 6, claim 22*	1, 3, 4, 5, 11,12, 19, 25, 31-34

[ ] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents :
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
4 September 2008 (06-09-2008)	2 October 2008 (02-10-2008)

Name and mailing address of the ISA/CA	Authorized officer
Canadian Intellectual Property Office Place du Portage I, C114 - 1st Floor, Box PCT 50 Victoria Street Gatineau, Quebec K1A 0C9 Facsimile No.: 001-819-953-2476	Goran Basic 819- 953-2098

Box No. II **Observations where certain claims were found unsearchable (Continuation of item 2 of the**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons :

1. [ ] Claim Nos. :
   because they relate to subject matter not required to be searched by this Authority, namely :

2. [ ] Claim Nos. :
   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically :

3. [ ] Claim Nos. :
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III **Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows :

(see extra sheet)

1. [ ] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. [X] As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. [ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claim Nos. :
4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim Nos. :

Remark on Protest [ ] The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

[ ] The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

[ ] No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CA2008/001105

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
US5753931A	19-05-1998	NONE	
US7069153B2	27-06-2006	NONE	
US6064759A	16-05-2000	AU5174698 A WO9822860 A2	10-06-1998 28-05-1998
US6618155B2	09-09-2003	CA2355557 A1 CA2355756 A1 CA2599472 A1 US2002025061 A1	23-02-2002 23-02-2002 23-02-2002 28-02-2002

The claims are directed to a plurality of inventive concepts as follows:

Group A - Claims 1-12, 19-34 are directed to a method and a system for measuring at least one physical dimension of a target comprising the step of acquiring a single digital image of the reflected light line of the target.
Group B - Claims 13-18 are directed to a method of measuring physical dimensions of a target comprising acquiring first and second image of the target and subtracting the first digital image from the second digital image.

The claims must be limited to one inventive concept as set out in Rule 13 of the PCT. The method from group B can not be implemented on the system from group A.