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(54) METHOD AND SYSTEM FOR DETERMINING THE ROUNDNESS OF A GOLF BALL

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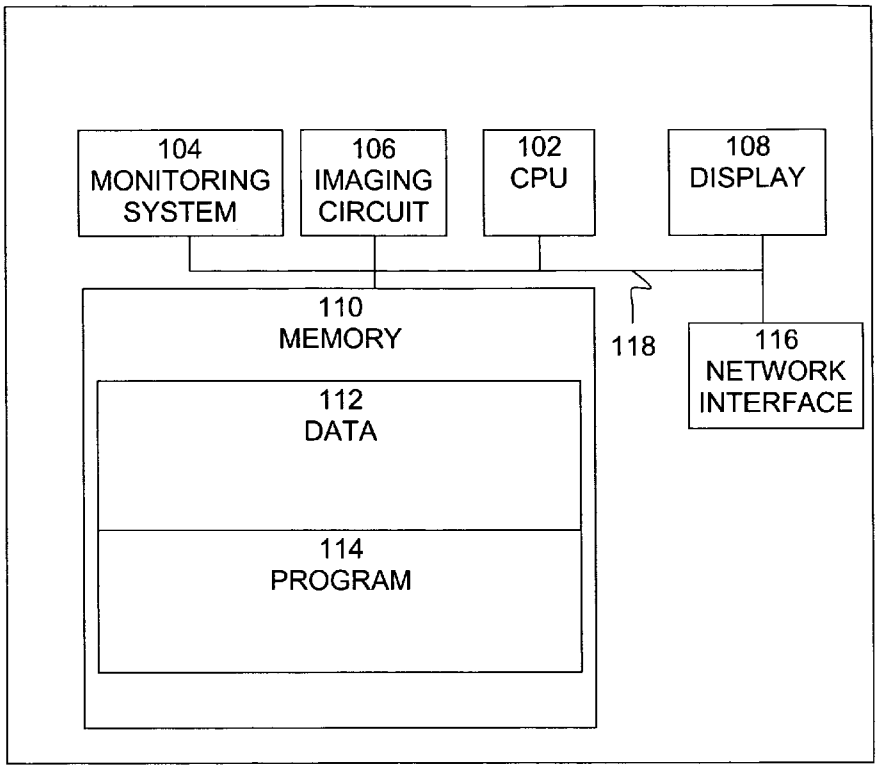
(52) **U.S. Cl.** **101/484**

(57) **ABSTRACT**

A golf ball is illuminated with diffused back lighting. CCD images of the golf ball are taken while the golf ball is being illuminated with the diffused back lighting. The edge or circumference of the golf ball is captured and sharply defined in the CCD images. The uniformity of the circumference may be determined by evaluating the radius of the object's circumference in an image, where an image is generated for n points around the circumference of the object, such as every 20° or 30°. By rotating the game ball, preferable with a battery operated stepper motor, the surface of the golf ball can be mapped.



100

Fig. 1

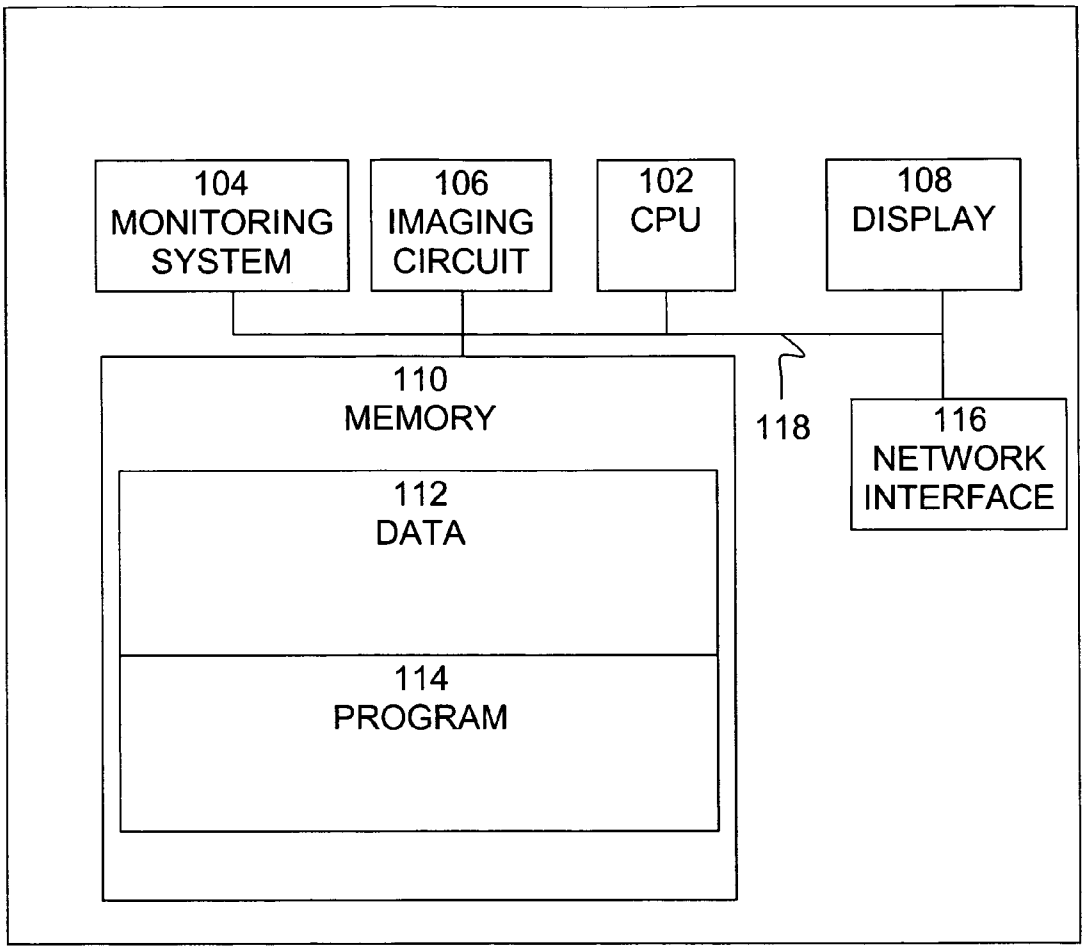

104
MONITORING
SYSTEM
106
IMAGING
CIRCUIT
102
CPU
108
DISPLAY
110
MEMORY
118
116
NETWORK
INTERFACE
112
DATA
114
PROGRAM
100

Fig. 2

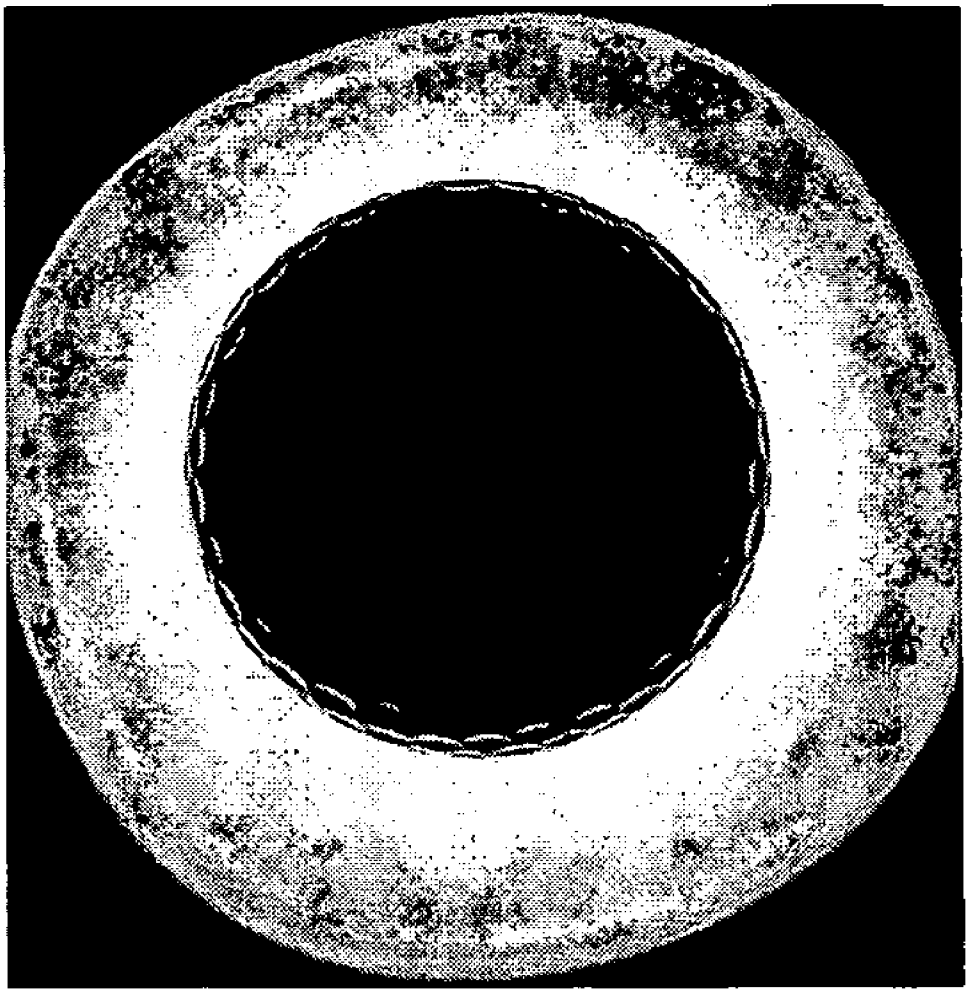


Fig. 3

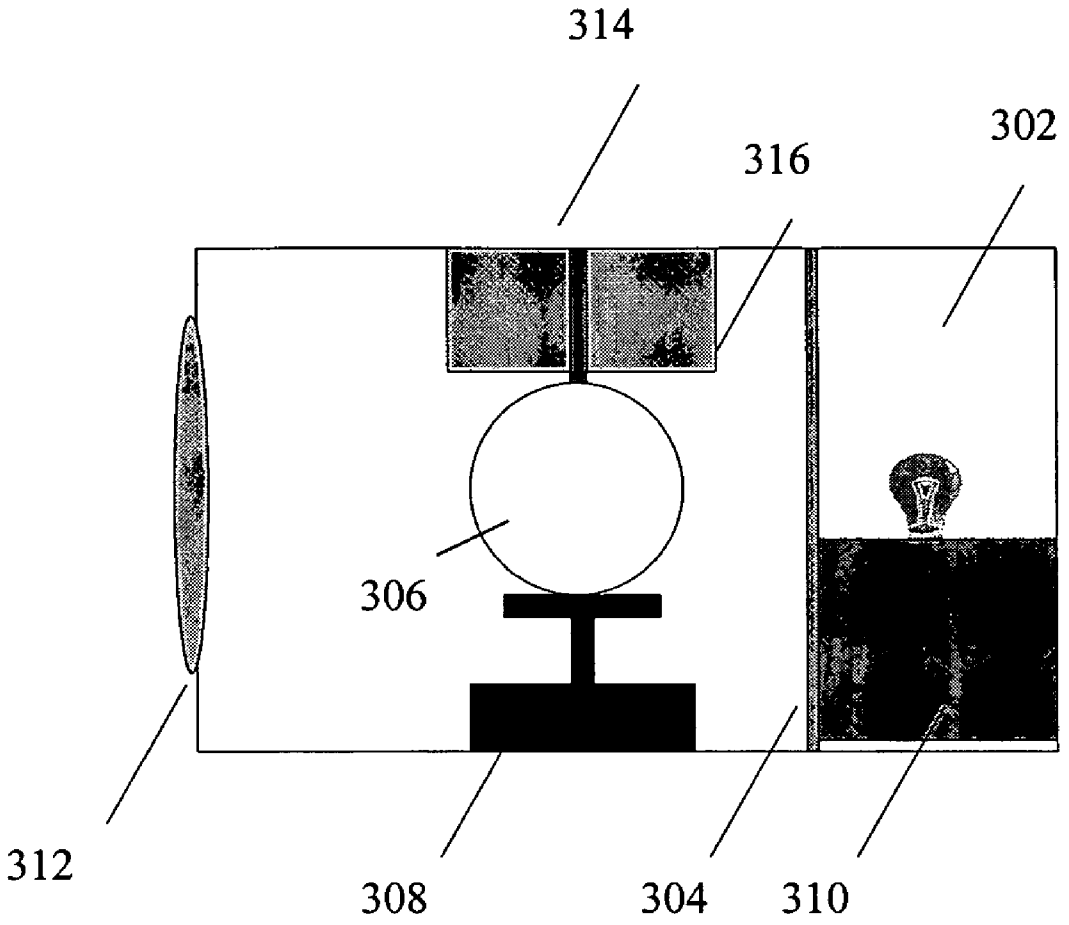
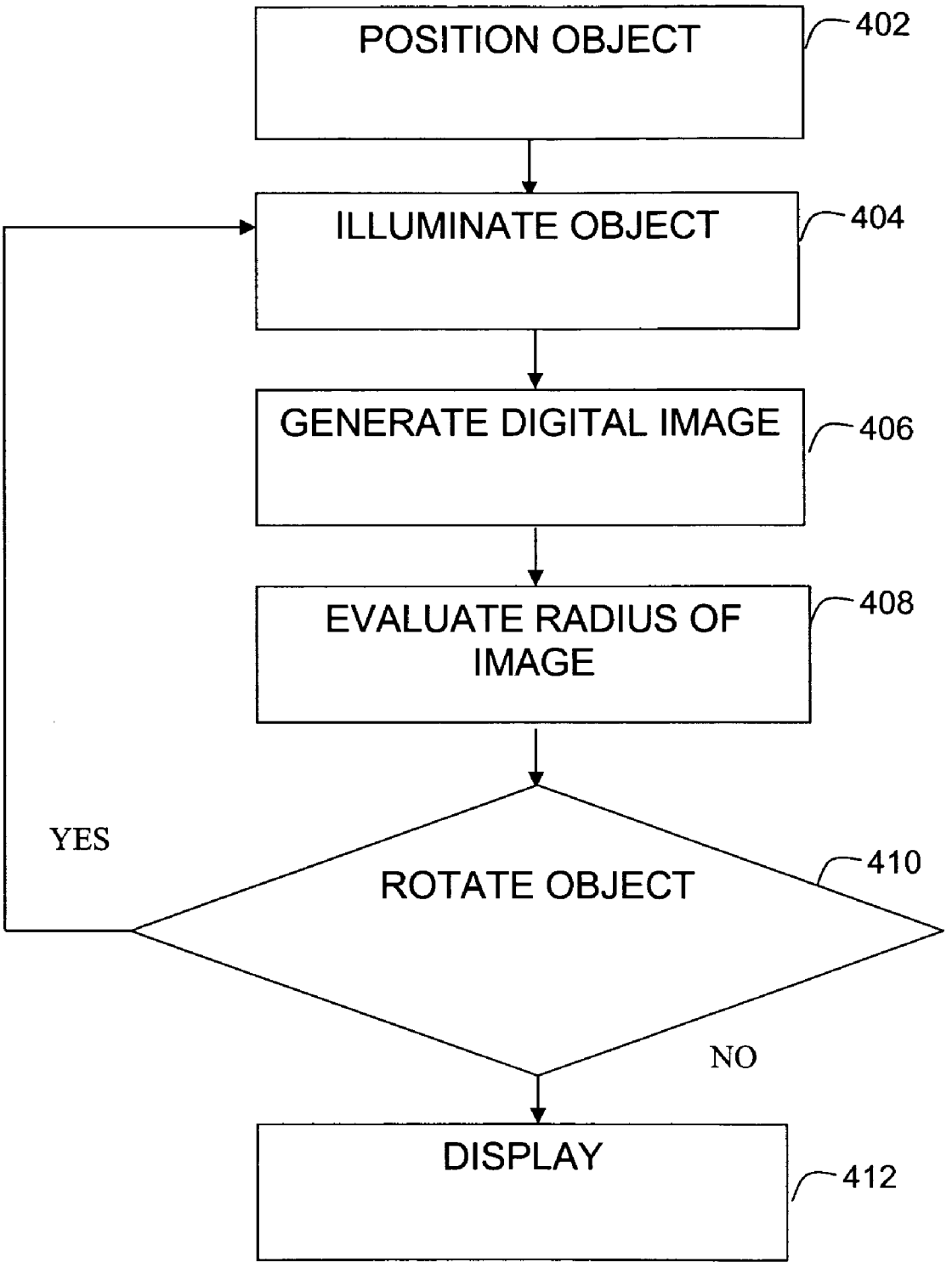


Fig. 4


POSITION OBJECT
402
ILLUMINATE OBJECT
404
GENERATE DIGITAL IMAGE
406
EVALUATE RADIUS OF IMAGE
408
ROTATE OBJECT
410
YES
NO
DISPLAY
412

METHOD AND SYSTEM FOR DETERMINING THE ROUNDNESS OF A GOLF BALL

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present invention claims priority to provisional Patent Application No. 60/654,000 filed Feb. 18, 2005, the entirety of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to a method, a system and a computer program product for determining properties of a golf ball. More particularly, the present invention relates to a method, a device and a computer program product for determining properties of a golf ball as a function of orientation using a hand-held portable device.

[0004] 2. Description of the Prior Art

[0005] Golf balls used by ordinary golfers vary in perfection. Imperfections may occur in golf ball manufacture that are not detected. More often, imperfections are introduced to a golf ball during usage of a golf ball. The imperfections that a golf ball is manufactured with and the imperfections introduced during usage of a golf ball affect the golf ball's flight on long drives or the golf ball's roll or direction when putted on a green. As a consequence of golf ball imperfections, the quality of a golfer's game may be reduced by factors not within his or her control. The enjoyment of the game as a challenge of skill is thus adversely affected.

[0006] Techniques have been developed to monitor golf ball quality in order to identify imperfections so that they do not have an impact on a game of golf. Techniques developed to determine the spherical shape of a golf ball implement gauges, various types of rings, and tubes which may be used. More recently, machine vision techniques have been described for determining the orientation of golf balls. These techniques print logos with respect to golf ball orientation and automation of this printing greatly improves golf ball manufacturing. This is important as golfers rely on the consistent placement of the logo to orient a ball for play. Other techniques inspect the repeated patterns, such as dimples, found on golf balls or the game ball to locate the position for printing a logo. The use of special lighting for obtaining CCD images of spherical objects, such as golf balls, has been implemented for visual or camera assisted evaluation of the golf ball patterns. However, the technologies currently available rely on visual interpretation of differences between a reference and the game ball. In addition, the technologies currently available focus on one kind of potential defect.

[0007] Accordingly, there is a need for a device to monitor the differences in properties between golf balls. There is a need for the device to be lightweight, and hand-held. There is a further need for the device to employ CCD images to assist a golfer in determining the properties of a golf ball. There is a further need for the device to determine a variety of properties of a golf ball. There is a further need for the device to determine the properties of a golf ball that directly affect putting. There is a further need for the device to determine a golf ball's out-of-roundness, size variations (oversized or undersized), balance, and blemishes on the golf ball surface. Also important is the golf ball's elastic properties that influence the length of drives.

SUMMARY OF THE INVENTION

[0008] According to embodiments of the present invention, a method, a device and a computer program product for determining properties of a golf ball as a function of orientation using a hand-held portable device are provided. The method illuminates a golf ball with diffused back lighting. CCD images of the golf ball are taken while the golf ball is being illuminated with the diffused back lighting. The edge or circumference of the golf ball is captured and sharply defined in the CCD images. The uniformity of the circumference may be determined by evaluating the radius of the circumference at n points around the circumference, such as every 20° or 30°. The evaluation of the radius is well known, for example as described in the publication Machine Vision, by E. R. Davies, which is hereby incorporated by reference in its entirety. By rotating the game ball, preferable with a battery operated stepper motor, the surface of the golf ball can be mapped. The generation of the CCD images, from an imaging system, such as the Scout™, may be triggered by the position of the stepper motor so as to have a correlation between image and ball position. The use of the logo as a reference point is of value in this regard.

[0009] In an embodiment of the invention, the uniformity of the circumference may be determined by the imaging system.

[0010] In an embodiment of the present invention, the uniformity of the circumference may be determined by a system separate from the imaging device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The above described features and advantages of the present invention will be more fully appreciated with reference to the detailed description and appended figures in which:

[0012] **FIG. 1** depicts an exemplary functional block diagram of a device in which the present invention can find application;

[0013] **FIG. 2** depicts an exemplary image of a golf ball with diffusive back lighting; and

[0014] **FIG. 3** depicts an exemplary schematic of the monitoring system **104** shown in **FIG. 1**.

DETAILED DESCRIPTION OF THE INVENTION

[0015] The present invention is now described more fully hereinafter with reference to the accompanying drawings that show embodiments of the present invention. The present invention, however, may be embodied in many different forms and should not be construed as limited to embodiments set forth herein. Appropriately, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the present invention.

[0016] According to embodiments of the present invention, a method, a device and a computer program product for determining properties of a golf ball as a function of orientation using a hand-held portable device are provided.

The method illuminates a golf ball with diffused back lighting. CCD images of the golf ball are taken while the golf ball is being illuminated with the diffused back lighting. The edge or circumference of the golf ball is captured and sharply defined in the CCD images. The uniformity of the circumference may be determined by evaluating the radius of the object's circumference in an image, where an image is generated for n points around the circumference of the object, such as every 20° or 30°. The evaluation of the radius is well known, for example as described in the publication Machine Vision, by E. R. Davies, which is hereby incorporated by reference in its entirety. By rotating the game ball, preferable with a battery operated stepper motor, the surface of the golf ball can be mapped. The generation of the CCD images, from a imaging system, such as the Scout™, may be triggered by the position of the stepper motor so as to have a correlation between image and ball position. The use of the logo as a reference point is of value in this regard.

[0017] **FIG. 1** depicts a functional block diagram of a system **100** in which the present invention can find application. In the embodiment of **FIG. 1**, the system **100** is a handheld device operable to determine the properties of a golf ball as a function of the golf ball's orientation using CCD images of the golf ball at different orientations with diffused back lighting. In the **FIG. 1** embodiment of the present invention, the system **100** includes a processor (CPU) **102**, imaging circuitry **106**, memory **110**, data **112**, display **108**, and program **114**. In the **FIG. 1** embodiment, imaging circuitry **106** is a CCD camera that captures diffused back lighting and generates at least one image of an object, such as a golf ball, with diffused back light for determining the uniformity of the circumference of the object by evaluating the radius of the object's circumference in the at least one image. In an embodiment of the present invention, an image of the object is generated at n points around the object's circumference. In an embodiment of the present invention, the radius is evaluated at orientations between 20 degrees and 30 degrees around the circumference and an image is taken at each orientation.

[0018] In the **FIG. 1** embodiment of the present invention, images of the object can be generated in response to the orientation the object as directed by a stepper motor in monitoring system **104** and provided to memory **110**. For example, a stepper motor can change the orientation of a golf ball to a new orientation that is **20** degrees from a previous orientation and take an image of the golf ball at the new orientation. This process can be repeated until sufficient images of the golf ball are generated at the different orientations. The images are provided in a code suitable for further digital signal processing by CPU **102**. The CPU **102** is a microprocessor, such as an INTEL PENTIUM® or AMD® processor, but can be any processor that executes program instructions in order to carry out the functions of the present invention. In an embodiment of the present invention, the images generated by image circuitry **106** are provided to a memory remotely located from system **102** by wirelessly transmission using network interface **106**. In the **FIG. 1** embodiment of the present invention, memory **110**, monitoring system **104**, imaging circuit **106**, CPU **102**, display **108** and network interface **116** communicate using bus **118**

[0019] In the **FIG. 1** embodiment of the present invention, the memory **110** is coupled to CPU **102** and stores program **114** and data **112**. The data **112** includes, but is not limited to, images depicting the object with diffuse back lighting in different orientations and edge property data related to the evaluation of the radius of the object in each image in order to determine the uniformity of the object. In an embodiment of the present invention, the object is a golf ball. In the **FIG. 1** embodiment of the present invention, the program **114** provides the functionality associated with determining the properties of a golf ball including, but not limited to, the uniformity of the golf ball's circumference and the elasticity of the golf ball, as executed by the CPU **102**. In an embodiment of the present invention, the program **114** is designed to determine the uniformity of the golf ball's circumference by evaluating the edge properties of the golf ball using images of the golf ball taken in different orientation with back lighting at each orientation and presenting the results of the evaluation on display **108**. In an embodiment of the present invention, the program **114** is designed to determine the elasticity of the golf ball by applying forces to the object, such as a golf ball, and measuring the return force and displaying the magnitude of the return force on the display **108**. In an embodiment of the present invention, the program **114** is designed to determine the balance of the golf ball by rotating the object, such as a golf ball, and measuring the center of gravity and displaying the magnitude of the center of gravity on the display **108**.

[0020] **FIG. 2** depicts an exemplary image of a golf ball with diffused back lighting. In **FIG. 2** embodiment of the present invention, the illumination of the golf ball with diffused back lighting provides the circumference of the golf ball in a sharply defined manner. A plurality of images like the image of **FIG. 2**, where the each image is an image of the golf ball at a different orientation, can be used to determine the uniformity of the circumference of the golf ball.

[0021] **FIG. 3** depicts an exemplary schematic of a monitoring system **104** shown in **FIG. 1**. In an embodiment of the present invention, the monitoring system **104** includes a light source **302**, a diffuser screen **304**, golf ball **306**, stage and stepper motor assembly **308**, battery casing **310**, monitoring system housing **312**, door **314** and shaft assembly **316**. The light source **302** illuminates an object for which the uniformity of its circumference is to be measured with a back light. In an embodiment of the present invention, the light source includes, but is not limited to, a filament bulb, a fluorescent bulb, and a solid state light emitting diode. The light is transmitted through diffuser screen **304**. In an embodiment of the present invention, the diffuser screen **304** can be a uniformly textured paper, plastic and glass sufficiently opaque such that the edges are highlighted but the surface of the golf ball is not.

[0022] In the **FIG. 3** embodiment of the present invention, the motor assembly **308** receives an object, such as a golf ball, to determine the uniformity of the object's circumference and the object's elasticity. In an embodiment of the present invention, the motor assembly **308** includes as stage and a stepper motor. The stage of motor assembly **308** receives an object, such as a golf ball, for inspection in accordance with the present invention. In an embodiment of the present invention, the stage can have a concave configuration to increase the stability of the object on the stage. The stepper motor can rotate the object. In an embodiment of the present invention, the stepper motor rotates a golf ball

between 20 degrees and 30 degrees and triggers a camera to generate an image of the golf ball with back light after each rotation so as to map the circumference of the golf ball using a plurality of images of the golf ball. In an embodiment of the present invention, the logo on the golf ball can be used a reference point for rotating the golf ball. Batteries in case **310** powers the stepper motor and light source **302**.

[**0023**] The Door E (**314**) allows for the object to be inserted into monitoring system **104** and includes a shaft **316** that centers the golf ball into the concave surface of the stage to allow for wobble-free rotation of the golf ball. In an embodiment of the present invention, the shaft **316** is made from an appropriate plastic, such as nylon, so that the golf ball is supported, but not damaged during inspection. In an embodiment of the present invention, the end of this shaft **316** is concave to better support the golf ball. The monitoring system housing houses the components of monitoring system **104** and couples to a camera, such as imaging circuitry **106** having a lens with a short focal length appropriate for imaging the golf ball. The shaft **316** may also be elongated and flexible such that on fast rotation by the stepper motor, the balance of the golf ball may be determined. If the center of gravity is the center of the sphere for the golf ball, the ball will rotate without wobble. If the center of gravity is not at the center of the golf ball, the ball will rotate with a wobble, where the maximum excursion of the wobble is the direction of the center of gravity, the balance point. Several approaches may be used to determine the balance point, e.g., by use of the Scout™ imaging system whose image will identify wobble and by use of a marking system (not shown) where a ink mark is placed on the ball during rotation at the maximum of the wobble. The ink mark identifies the direction of the balance point such that a golfer can properly place the ball for putting.

[**0024**] The camera records the image of the golf ball and provides this data for evaluation of the edge properties. The camera also contains the electronics to select the number of images for evaluating the golf ball. Each image requires the stepper motor to change the orientation of the golf ball. The camera provides a range of options in selecting the number of images and therefore orientations for evaluation of the golf ball. In an embodiment of the present invention, 6 through 12 images may be used corresponding to 60° or 30° inspection angles. In an embodiment of the present invention, the data are evaluated by the processor of system **100**. In embodiment of the present invention, the data is transferred to a processor and software operable to perform the evaluations of the present invention.

[**0025**] **FIG. 4** is an exemplary flow chart for a method of determining the uniformity of the circumference of the object by evaluating the radius at n points around the object's circumference. The method begins in step **402**. In step **402**, an object, such as a golf ball is positioned on a stage of stepper motor. In step **404**, the object is illuminated with diffused back lighting. By illumination with diffuse back lighting, the circumference of a golf ball is sharply defined. In step **406**, a digital image of the object with the diffused back lighting is obtained and stored. In step **408**, the radius of the object is evaluated at n points around its radius. In step **410**, it is determined whether to rotate the object at a particular angle. If so, the object is rotated and steps **404** through **408** are repeated. Otherwise, the uniformity of the object is provided at step **412**.

[**0026**] While specific embodiments of the present invention have been illustrated and described, it will be understood by those having ordinary skill in the art that changes can be made to those embodiments without departing from the spirit and scope of the invention. For example, while the present invention concentrates on a single color digital image and stationary lost object analysis, it is understood that information from a series of images, a moving object or a specific object might advantageously be used as well. Also, while our application to golf balls has options for using UV and visible light, the method is not dependent on this choice.

What we claim is:

1. A method of determining the properties of an object as a function of the object's orientation, the method comprising:

providing the object to be evaluated;

generating a digital image of the object with diffused back lighting at a plurality of different orientations;

evaluating the radius of the object in each of the digital images of the object with diffused back lighting;

determining a first property of the object, wherein the first property of the object is the uniformity of the object's circumference based on the evaluation of the radius of the object in each of the digital images.

2. The method according to claim 1, further comprising illuminating a light source prior to generating each digital image.

3. The method according to claim 2, further comprising transmitting light from the light source through a diffused screen.

4. The method according to claim 1, further comprising rotating a stepper motor prior to generating each digital image.

5. The method according to claim 1, further comprising storing data pertaining to the radius of the object in each digital image.

6. The method according to claim 1, further comprising reporting the object's first property.

7. The method according to claim 1, further comprising applying force to the object and measuring the return force of the object to determine a second property of the object, wherein the second property is the elasticity of the object.

8. An apparatus for determining the properties of an object as a function of the object's orientation comprising:

a processor operable to execute computer program instructions; and

a memory operable to store computer program instructions executable by the processor, for performing the steps of:

generating a digital image of the object with diffused back lighting at a plurality of different orientations;

evaluating the radius of the object in each of the digital images of the object with diffused back lighting;

determining a first property of the object, wherein the first property of the object is the uniformity of the object's circumference based on the evaluation of the radius of the object in each of the digital images.

9. The apparatus according to claim 8, further comprising computer program instructions executable by the processor, for performing the step of illuminating a light source prior to generating each digital image.

10. The apparatus according to claim 9, further comprising computer program instructions executable by the processor, for performing the step of transmitting light from the light source through a diffused screen.

11. The apparatus according to claim 8, further comprising computer program instructions executable by the processor, for performing the step of rotating a stepper motor prior to generating each digital image.

12. The apparatus according to claim 8, further comprising computer program instructions executable by the processor, for performing the step of storing data pertaining to the radius of the object in each digital image.

13. The apparatus according to claim 8, further comprising computer program instructions executable by the processor, for performing the step of reporting the object's first property.

14. The apparatus according to claim 8, further comprising computer program instructions executable by the processor, for performing the steps of applying force to the object and measuring the return force of the object to determine a second property of the object, wherein the second property is the elasticity of the object.

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