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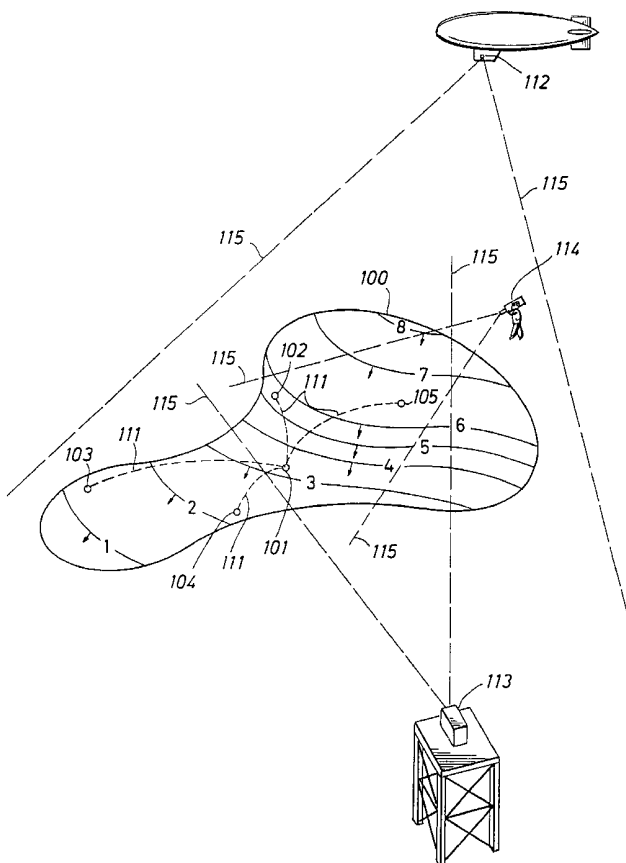
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(54) Title: SYSTEM FOR ENHANCING THE TELEVISED BROADCAST OF A GOLF GAME



(57) Abstract: A system for the enhancement of a
televised golf broadcast, which requires: obtaining
detailed topographic measurements of golf greens;
inputting these data into a Geographic Information
System (GIS) program, smoothing the data, and
generating contours on a selected interval; storing and
processing the contour data such that it may be viewed
from various other perspectives; selecting a real-time
televised image of a golf green from a plurality of
camera positions; synchronizing and superimposing
the contour database image over the televised feed;
computing and processing equations of motion which
take into account the location of the golf ball relative
to the golf cup, the weight of the golf ball, the effect
of the wind, the Stimp meter speed of the green,
and the gravitational influence of the slope of the
green, to determine a path the putt can take to roll
into the cup or to come to rest within 18 inches of
the cup; this system provides the viewer with a visual
image of an optimal path the golf ball can traverse
to result in a successful putt. With the addition of the
contours and the calculated trace of the putt trajectory,
the viewer has a visual assessment of the break of the
putt, without depending upon the announcers'
comments. Accordingly, the viewers visual experience
is substantially enhanced by knowing in advance of
the player's putt, the line which the ball must take to
the cup.

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1 the path and the weight with which the ball must be struck along that path to roll the golf
2 ball into the cup, or to come to rest no further than 18 inches past the cup.

3 An enhancement is embodied in this invention which will enable the viewers to
4 know the proper line for the putt in advance of the putt being struck. The projection and
5 display of lines of equal elevation, known as contour lines, onto the real-time televised
6 image of the golf green provides the viewing audience with a depth of information
7 exceeding that which is normally available to the analyst who is assigned to that green.
8 These contour lines are spaced at intervals that can be indicated on the video screen.
9 Small arrows can be affixed at right angles to the contour lines showing the viewers the
10 downslope direction on the green.

11 Elevation numbers can be shown on the contour lines, and these together with
12 the arrows pointing downslope easily enable the viewers to assess the difficulty of the
13 various players' putts by studying the direction and amount of slope, i.e. either uphill,
14 downhill, side-hill, or flat, between each golf ball and the golf cup. With minimal training
15 by the analyst, the unfamiliar viewers can readily determine, using the present invention,
16 which putts are the least or the most difficult, thereby greatly enhancing their viewing
17 enjoyment of the match.

18 The broadcast networks have at various times attempted to show the break, i.e.
19 the curved path, of the putts by having the analyst draw a crude line on the video screen
20 between the golf ball and the cup. However, this line is only a rough approximation of
21 the true trace (track or trajectory) of the putt and the viewers are still not certain of the
22 break until after the golf ball has been struck by the player and is rolling toward the cup,
23 at which time they can actually perceive it on the two dimensional TV screen.

24 The broadcast networks have also attempted the use of various graphic depictions
25 of the greens. These graphics have generally been rotated to give the illusion of a three
26 dimensional view of the green. However, because an exaggerated vertical scale is usually
27 used on these graphics, there must be a return from graphics to the real-time television

1 image of the green before the player strikes the ball. Since the real-time image does not
2 allow the viewers to visually determine the break in advance of the ball being struck, it
3 still leaves the viewer dependent upon the live broadcast analyst for information
4 regarding the break on each players golf ball.

5 Another useful enhancement embodied in this invention is the projection and
6 display of the calculated line of the putt on the real-time video screen. This projection is
7 based upon an equation of motion which calculations incorporate the weight of the ball;
8 the relationship between the ball and the hole; the Stimpmeter measurement or speed
9 (frictional resistance) of the green; and the gravitational influence on the roll of the ball.
10 This enhancement adds immensely to the viewers' enjoyment by allowing them to see
11 the trace (track or trajectory) of the path of the putt annotated and displayed on their
12 television screen before the putt is struck.

13 The addition of these enhancements to the golf tournament viewers' television
14 screen provides more information for the viewers use than has previously been available
15 and can stimulate their interest in more closely watching golf tournament activities which
16 take place on the greens.

17 SUMMARY OF THE INVENTION

18 In accordance with the methods and apparatus of the present invention, a system
19 is disclosed which enables the viewers of a televised broadcast of a golf tournament to
20 determine the proper line of a player's putt toward the golf cup, before the player strikes
21 the golf ball, thereby greatly enhancing the viewers' enjoyment of the game. This system
22 comprises methods and apparatus for: obtaining detailed topographic measurements of
23 the greens on a golf course; inputting these data into a Geographic Information System
24 (GIS) program, smoothing the data, and generating contours on a selected interval to
25 generate a database image; storing and processing the contour data such that it may be
26 viewed from various perspectives; selecting a real-time televised image of a golf green

1 from a plurality of camera positions; synchronizing and superimposing the aforesaid
2 database image over the televised live video feed to achieve registration; computing and
3 processing an equation of motion which takes into account the initial ball position, the
4 speed of the green, the wind effect, and the gravitational influence of the slopes, to
5 determine an optimal path the ball can take to roll into the golf cup, or to come to rest
6 within 18 inches of the cup; and displaying the combined images along with the
7 projection of the calculated ball path on a real-time televised broadcast. Before the golfer
8 strikes the golf ball toward the cup, this system provides the viewers with a visual image
9 of a path the golf ball could traverse to result in a successful putt.

10 Referring to FIG. 4, the first step in the process is to acquire detailed topographic
11 data on the putting greens of a selected golf course. Accurate surveying instruments must
12 be used, which will provide elevations with minimal error. These data are then loaded
13 into a system control computer database and processed to create smoothed contours on
14 desired intervals, which best portray the slope details of the golf greens. One of the
15 greens can then be selected for viewing, and the appropriate contours can be brought up
16 out of the database. Concurrently, a real-time television image of the selected green, or
17 an image which was stored in the database before tournament play began, can be
18 retrieved from the database, along with the contours for that green, and the two images
19 are then synchronized and registered.

20 Television broadcast cameras are traditionally deployed in a plurality of positions
21 around golf greens at a golf tournament, with particular emphasis on three specific
22 camera positions. The first camera is positioned aboard a lighter-than-air blimp, which
23 circles over the golf course and which has the capability of focusing on any of the greens
24 on the course. A second camera, known as the platform camera, is typically positioned
25 immediately adjacent to each green on a platform reserved specifically for the use of this
26 camera. Thirdly, multiple green-side positions are available to a shoulder-held camera
27 which can be used to obtain close-up shots of the players' activities on and around the
28 golf greens.

1 The real-time TV picture of a green can then be selected. This picture originates
2 from one of the three camera positions assigned to monitor the green. As the approaching
3 players' golf balls land on the green and come to rest, their positions are determined and
4 registered using a mouse, light pen, digitizing tablet, or other pointing device, and this
5 data is incorporated into the database. Alternatively, the rest positions of the golf balls
6 and the position of the shoulder-held camera can be located and registered by shooting
7 them in with a laser surveying instrument or in the case of the shoulder-held and blimp
8 cameras, they can be located and registered using a Global Positioning System (GPS)
9 package attached to the cameras. Similarly, pattern recognition techniques could be used
10 to register the ball and camera positions by comparison with the video image of the
11 empty green held in the database. In any event, these initial positions, which are
12 necessary as input data to the system of the present invention, are obtained by one of the
13 above described methods.

14 In the next step, equations of motion which take into account the physical
15 relationships between the balls, the cup, the speed of the green, and the gravitational
16 influence of the slopes, are used to calculate and to determine a trajectory which will
17 result in a golf ball rolling into the cup, or coming to rest within 18 inches of the cup.
18 Successively, the trajectory of each remaining putt can be calculated and can be displayed
19 on the screen, and these annotations superimposed over a live image, prior to the players'
20 putting the golf balls.

21 There are many variations which could be employed in the use of these three
22 camera positions. However, one camera position sequence which can be visualized
23 begins with the overhead blimp camera zooming-in on a green which is being approached
24 by a group of golfers. The contours for that specific green can be synchronized with the
25 real-time television feed of that green and displayed on the screen prior to or as the
26 approach shots are landing on the green. Prior to the arrival of the players, the announcer
27 can discuss with the viewing audience the preferred landing area on the green and the
28 effect of the contoured slopes on the individual players putts as their golf balls land on

1 the putting surface.

2 The televised picture can then be switched from the blimp camera to the platform
3 camera, to focus on the overall green, and then zoomed-in to focus on a specific player's
4 putt. When the player has finished examining the slopes of the green in relation to his or
5 her putt, and is moving into position to strike the putt, the televised picture can then be
6 switched to the green-side, shoulder held camera, which has typically taken a position
7 behind the player, in line with the hole, such that the roll of the green, or the break of the
8 putt can best be visually observed by the television viewers. The contours which create
9 the break on the putt are in view on the screen in their proper perspective, and these
10 contours allow the viewers to anticipate the path which the putt will take prior to the ball
11 being struck. The calculated trajectory (track or path) of the putt can also be shown on
12 the screen and optionally can be left on while the putt is struck, or it can be removed just
13 prior to the players putt. This same general sequence of camera positions, using
14 principally the platform and shoulder cameras, could be repeated on each of the
15 remaining player's putts. The camera sequence described above or a plurality of
16 variations, can be used to display the enhancements contained in the present invention.

17 Advantages of this invention are the addition of the contours and the calculated
18 ball trajectory to the television viewers' screen. The presence of the contours will for the
19 first time allow the viewer to comprehend and read the slopes of the green, and the plot
20 of the trace of the ball trajectory will provide the viewer with a competent visual
21 assessment of the break of the putts before they are struck. This type of information and
22 degree of accuracy has never before been available to the audience viewing the broadcast
23 of a golf tournament.

24 Other features and advantages of this invention will be understood from the
25 following detailed description thereof when taken in conjunction with the accompanying
26 drawings which are intended as illustrative and not limitations.

1 BRIEF DESCRIPTION OF THE DRAWINGS

2 FIG. 1 is a plan view of a golf green.

3 FIG. 2 is a plan view of a golf green with topographic contours added.

4 FIG. 3 is a plan view of a golf green showing the types of camera positions and
5 perspectives and examples of ball trajectories.

6 FIG. 4 is a simplified flow chart depicting a process according to the invention.

7 FIG. 5 is a flow chart showing a computer process used to display occlusions on
8 a green.

9 FIG. 6 is a flow chart showing a computer process used to calculate the trajectory
10 of a golf ball.

11 FIG. 7 is a simplified flow diagram showing components of the main processor.

12 FIG. 8 is a block diagram showing the components used in the system of the
13 present invention.

14 DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

15 While this invention is susceptible of embodiment in several different forms,
16 there is shown in the drawings, and will herein be described in detail, one specific
17 embodiment of the invention. It should be understood, however, that the present
18 disclosure is to be considered an exemplification of the principles of the invention and
19 is not intended to limit the invention to the specific embodiment so described.

20 FIG.1 depicts a plan view of the outline of a golf green 100. In the middle of the
21 green is a golf cup 101, which is marked by a flag. Also situated on the golf green are
22 four golf balls 102,103,104, and 105. Although the viewers perspective of the outline of

1 the golf green 100 will vary dependent upon the camera location, the only thing they will
2 see when the initial televised image of the green 100 appears on their TV screen, is the
3 featureless two dimensional plan view shown in FIG. 1. This view shows no depth
4 perspective and as a result will give the viewer the impression that the line of the putts
5 for balls 102,103,104, and 105 may be straight into the golf cup 101. This is generally
6 not the case. However, in the present state of televised golf tournament presentations, the
7 viewer is completely dependent upon the opinions of the network commentator, for
8 information regarding the break or trajectory of these putts.

9 This invention embodies an enhancement of the viewers interest in a televised
10 golf tournament by providing specific annotated information to the viewer which will
11 enable them to perceive the green 100 in a 3-D perspective and to be able to visualize a
12 proper path for a players putt before it is struck. FIG. 2 shows the same golf green outline
13 100 seen in FIG. 1, with the addition of an example set of topographic contours 106.
14 Contours are lines of equal elevation. The viewer will be able to see in which direction(s)
15 the slope(s) of the green are tilted, by observing the numbers on the contour lines 107.
16 The numbers will increase from the lowest numbered (1) contour 108 to the highest
17 numbered (8) contour on the green 109, i.e., the green slopes from contour 8 down to
18 contour 1. Small vector arrows 110, which are orthogonal to the contour lines, pointing
19 in a downslope direction may be affixed to each contour line 106. The contours 106 may
20 be shown as thin solid or dashed lines; by different colored lines or shading between
21 contours; by a blinking line; or by a variation in the brightness or by any other shape or
22 graphic technique deemed appropriate. All such variations are within the concepts of the
23 present invention. Further, the hole 101 may also be highlighted with a bright color, such
24 as yellow, or by other appropriate means to enhance its visibility to the television viewer.

25 Gravity acts on a moving golf ball at any point in its trajectory causing it to roll
26 into a position parallel to the maximum pitch of the slope, and therefore at a right angle
27 to the contours 106. Accordingly, if the ball is rolling across a slope, it will curve until
28 it is rolling straight down the slope. If it is rolling upward across a slope, it will tend to

1 curve rapidly in a downhill direction as it slows down. As an example of this principle,
2 the contour 106 configuration shown in FIG. 2, relative to the golf ball positions
3 102,103,104,105, would immediately indicate to the viewers that all four putts would
4 need to travel along a curved rather than a straight line to end up near the golf cup 101.

5 In FIG.3 the short dashed lines 111 between the four golf ball positions
6 102,103,104,105 and the cup 101 illustrate trajectories 111 that the golf balls could
7 follow in response to the influence of gravity as they traversed the contoured surface of
8 the green toward the golf cup 101 from the four ball positions. The actual trajectories
9 may be calculated using these equations of motion which take into account the other
10 factors influencing the path of the golf balls. These factors are subsequently discussed in
11 more detail under the section on "Golf Putt Trajectories".

12 Also shown on FIG.3 are the three principal camera positions typically used
13 during the televised broadcast of a golf tournament. They are the blimp-based camera
14 112, the platform camera 113, and the shoulder-held camera 114. The blimp-based
15 camera 112 generally circles over the tournament golf course at an elevation of 1000-
16 1200 feet and has the ability to zoom-in on any of the greens 100. A fixed platform
17 camera 113 is installed adjacent to each green where television coverage is planned. The
18 third camera is a shoulder-held camera 114 which moves freely around the golf course
19 filming footage of the competitors. When the players reach the green 100, this camera
20 114 often takes a position at the edge of the green 100 behind the player whose turn it is
21 to putt, to give the television viewers the best camera angle to observe the break or
22 trajectory of the players golf ball after it is struck.

23 The long dashed lines 115 radiating from each camera are examples of possible
24 perspectives which might be observed by these cameras. The illustration shown in FIG.3
25 is intended to demonstrate the wide field of view 115 of the blimp camera 112; the more
26 restricted field of view 115 of the platform camera 113; and the limited field of view 115
27 generally seen by the shoulder-held camera 114.

1 FIG.4 is a simplified flow chart or diagram depicting the process according to the
2 concept of the invention. Topographic data from each green on a golf course are acquired
3 and loaded into a system control computer database 401. These data are then processed
4 and smoothed 402, and contour maps on selected intervals prepared and stored. TV
5 images of each green are also digitized and loaded into the database well in advance of
6 the beginning of tournament play. Platform based television cameras are typically put
7 into position 400 on all greens where televised coverage of a tournament is desired. A
8 blimp carrying a television camera generally circles the golf course overhead taking
9 pictures and roving cameramen move about the course obtaining coverage of the
10 competing golfers. When a green is selected 403 by the Television Director for viewing,
11 one of the camera positions is also selected 405, i.e. camera 406, 407, or 408 is selected
12 as a video source for this coverage. The stored contours, green outline, and cup position
13 for the selected green are retrieved at step 409, and are synchronized, and registered with
14 the televised image of the golf green 410. The contours are then superimposed over the
15 real-time TV picture of the green 411. As golf balls arrive on the green and come to rest,
16 their location is registered 412 and stored in the database. The equations of motion then
17 calculate an optimal path or trajectory which each ball should follow on its path to the
18 cup, to come to rest within 18 inches of the cup 413. The trace of this line or trajectory
19 is displayed at step 414 on the viewers live video screen before the putt is struck. It
20 should be appreciated by those of skill in the art that, rather than a television, the live
21 video screen and the processing power for carrying out the present invention may be
22 included in a hand-held device to assist a golfer is determining the optimal path or
23 trajectory of the golf ball, rather than a home viewing audience.

24 In a real-time televised golf tournament presentation, the present invention can
25 bring up on the TV screen an image of the green 100 chosen for viewing from one of the
26 plurality of camera positions, with the contours 106 superimposed over the real-time
27 televised picture. Registration of the contour data with the real-time TV picture is
28 accomplished through the use of known pattern recognition technology, which aligns the
29 perspectives of the surveyed green-edge with the live televised green-edge. This

1 registration enables the use of a mouse, pointer, or a computer tablet to locate precisely
2 the at-rest position of the balls 102, 103, 104, 105, the cup 101, and the shoulder-held
3 camera 114 relative to the information contained within the database in the main
4 processor 200. These positions may also be registered onto the live image by shooting
5 them in with a laser surveying instrument.

6 On each green 100 where televised coverage of a tournament is desired, the
7 location of the platform camera 113 should be determined in advance of tournament play
8 by conventional surveying methods, and its three dimensional x,y,z coordinates stored
9 in database 200-a, along with the outline of the green-edge.

10 The preferred method for determining the location of the shoulder-held camera
11 114 would employ the use of a Global Positioning System (GPS) receiver-radio
12 transmitter package. One such unit is marketed by the Trimble Company of Sunnyvale,
13 California, and would be attached to the camera 114 to obtain the x,y,z coordinates
14 necessary for registration with the database 200-a. The same method could be used to
15 locate the position of the blimp-based camera 112 for registration of an image of the
16 green 100 and the contours 106.

17 Referring to FIG.5, an important aspect of this invention is the ability of the
18 computer process 500 to allow the players to walk up onto the green 100 and obscure or
19 occlude the contours 106 underfoot and in the background of their images. This effect is
20 accomplished by storing the image of a green 100 in the database 501; loading into the
21 database 501 the live video image of the selected green 502; registering these two images
22 503; subtracting out the occluded images of the golfers as the difference between the
23 stored and the registered real-time images 504; overlaying the stored topographic contour
24 image on top of the real-time image of the green 506; and then projecting the real-time
25 image of the golfers back onto the contour overlay for display 507 on the television
26 viewers screen.

27 When the ball trajectories 111 are to be projected onto the television screen, they

1 will be overlaid onto the image of the green 100, or superimposed onto the contours 106,
2 as appropriate, before the subtracted image of the golfers is overlaid at step 507. These
3 trajectories may be represented graphically by various thicknesses of solid, dashed, or
4 dotted lines, or by many other symbol configurations, as desired. These symbols may
5 also be presented using various colors or shades of light. The trajectories 111 are
6 calculated using equations of motion which compute a range of lateral movement of the
7 players golf balls, taking into consideration the frictional coefficient of the greens, the
8 gravitational influence of the slope of the green, and the location of the golf balls relative
9 to the golf cup 101, to arrive at the optimum trajectories 111 for the individual putts.

10 *Golf Putt Trajectories*

11 This invention utilizes basic principles of physics to compute a possible range of
12 lateral trajectories that a golf ball may traverse to come within a specified distance of the
13 golf cup 101. The starting point for this procedure is summarized in FIG. 6 and is the
14 establishment of a digital database 601 of very dense topographic measurements of the
15 entire area of the green 100 and some of the surrounding area. Approximate x,y,z
16 coordinates on the green surface could be obtained with the most accurate GPS
17 equipment. However, the error inherent in this survey system would provide poor results
18 with this invention on the relatively flat areas of the green. The most accurate
19 topographic measurements can be obtained through the use of conventional surveying
20 equipment or 3-D laser mapping equipment, such as the Cyrax System, marketed by Cyra
21 Technologies of Oakland, California. From these data a numerical model 602 of the
22 surface of the green 100 and surroundings is computed. This numerical model serves a
23 variety of purposes. From it, contours 106 may be computed for easy visualization of the
24 green topography. Additionally, the green model makes it possible to compute the slopes
25 everywhere on the green quickly and accurately. This facilitates the computations of the
26 effects of gravity on the trajectory 111 of a golf ball when it is putted toward the golf cup
27 101.

28 The following equations of motion are used iteratively to calculate the motion of

1 the golf ball and to derive a trajectory as it traverses a green 100 of varying slope. The
 2 x and y-subscripts used in the equations of motion refer to the component of the
 3 particular variable in the x or y-direction.

4	1. $v_{0x} = v_0 \cos\theta$	6. $f_y = f \cos\alpha \sin\beta$	11. $\Delta x = \Delta d \cos\theta$
5	2. $v_{0y} = v_0 \sin\theta$	7. $a_x = g_x - f_x$	12. $\Delta y = \Delta d \sin\theta$
6	3. $g_x = g \sin\alpha \cos\beta$	8. $a_y = g_y - f_y$	13. $v_x^2 = v_{0x}^2 + 2 a_x \Delta x$
7	4. $g_y = g \sin\alpha \sin\beta$	9. $v_x = v_{0x} + a_x \Delta t$	14. $v_y^2 = v_{0y}^2 + 2 a_y \Delta y$
8	5. $f_x = f \cos\alpha \cos\beta$	10. $v_y = v_{0y} + a_y \Delta t$	

9

10 The definitions of the symbols used in the above equations are as follows:

- 11 $\theta =$ Angle of direction of travel measured from the x-direction
- 12 $\alpha =$ Slope angle measured downward from horizontal
- 13 $\beta =$ Angle of direction of maximum slope at a point measured from
- 14 the x-direction
- 15 $\Delta d =$ Distance traveled along trajectory in a single computational step
- 16 $v =$ Velocity at any time after having traveled some distance, $s(x,y,z)$
- 17 $v_0 =$ Initial velocity
- 18 $a =$ Acceleration factor – combines both gravitational and frictional
- 19 forces ($g - f$)
- 20 $g =$ Gravitational acceleration value

- 1 $f =$ Deceleration term accounting for frictional effects
- 2 $\Delta x =$ Distance traveled in x-direction in a single computational step
- 3 $\Delta y =$ Distance traveled in y-direction in a single computational step
- 4 $\Delta t =$ Time required during a single computational step

5 FIG.6 is a flow chart showing the computer process required to calculate an
6 optimal trajectory 111 which a golf ball can follow to result in a successful putt, *i.e.*, one
7 which rolls into the cup 101 or comes to rest within 18 inches of the cup 101. As is
8 shown in FIG. 6, to start this process 600, each green 100 must be accurately surveyed
9 as previously discussed. In addition to the dense topographic measurements on each
10 green 100, it is necessary to measure multiple reference points 601 around the perimeter
11 of the green 100. Such reference points 601 should be permanent features of the area
12 surrounding the green 100 since the topographic database can be usable for many years.
13 The sprinkler heads and drains at the edge of the green 100 are permanent features and
14 are particularly well suited for this purpose. Image registration is accomplished by using
15 these features around the golf green which were surveyed in during the data gathering
16 process. The position of the sprinkler heads and the shape of the outline of the green are
17 used to register the database green image with the live video image.

18 Since the cup 101, as shown in FIGs. 1 and 2, is moved each day during
19 tournament play, it is necessary to re-enter the new cup 101 location into the database
20 200 daily. If the distance from the cup 101 to three or more of the reference points 601
21 is measured, then simple geometric computations suffice to accurately locate the cup 101
22 position. One most straightforward method is that of intersecting circles. An arc of a
23 circle having the ball-to-cup distance as radius and centered at the reference point 601 is
24 calculated for each reference point 601 used in locating the cup 101. Any arc calculated
25 for an erroneous measurement will noticeably diverge from the other values. That is why
26 multiple reference point 601 measurements are necessary. All of the points of intersection

1 of the arcs or the closest points for non-intersecting arcs are averaged to yield the
2 optimum cup 101 coordinates. The necessary measurements can be made very quickly
3 with a 100 foot steel tape measure. The new cup position each day could be located
4 accurately with a steel tape, or surveyed in with conventional surveying instruments, or
5 its x,y,z coordinates could be input into the database 200 using a mouse, pointer, or a
6 computer keyboard, etc.

7 The numerical surface used to model the green surface 602 is computed from the
8 data samples recorded when the green 100 was surveyed (e.g., 3-D laser scan). The data
9 as collected is pre-processed using a data decimation process that yields a version of the
10 data in which the average point-to-point distance in the data is a specified distance,
11 typically 0.5-1.0 inches. The decimation process involves computing a moving window
12 over the sorted data and replacing all points falling within a window by a single value
13 that is the average of all of the points falling within the window. The decimation window
14 is square with the sides being the length of the desired average point-to-point separation.
15 Averaging, rather than deleting excess points, guarantees that the data-set is consistent
16 for the chosen decimation window.

17 Once decimation is completed, a triangular mesh is constructed containing all of
18 the data points as the mesh nodes. The mesh geometry thus defines the geometric
19 relationship of each node to the surrounding nodes. Once the geometric relationships of
20 the points has been defined via the mesh geometry, x and y-partial derivatives (spacial)
21 are computed for each node thereby allowing a continuous surface to be computed
22 anywhere within the area covered by the mesh. Therefore at every location within the
23 mesh, both data and derivative values are defined. The decimation, triangulation and
24 interpolation functionality described above are implemented in a commercial mapping
25 software library such as Contour™ and GFT™ as provided by V-Tech of Missouri City,
26 Texas. If the data collected on a green 100 is obtained through the use of conventional
27 surveying equipment, there is no need to apply the decimation process.

28 To facilitate the slope computations, an integral part of the numerical processing

1 used to build the numerical surface model of the green 100 is a triangulation of the point
2 set. At each node of the triangulation, x and y directional derivatives are calculated.
3 These derivatives are the rate of change of elevation along the x and y directions
4 respectively. Derivative calculation at the nodes may be accomplished using a wide
5 variety of methods. Sometimes, local analytical surface fits are performed about each
6 node to define derivatives. Least squares fits to low order polynomials is also a useful
7 method. Another very simple, but effective method is to fit a plane through each of the
8 triangles having a common node. Then a weighted averaging of the slope components
9 is performed to define the values at the node. The weights are usually dependent on the
10 areas of the contributing triangles. It is possible to rapidly determine which triangle any
11 point falls within along the calculated trajectory. The slope and z-value anywhere within
12 a triangle may be easily interpolated from the corner node values. Along any edge of a
13 triangle, the slopes are simply linearly interpolated from one node to the next. The slope
14 components at an arbitrary point within a triangle are determined by first linearly
15 interpolating along the bounding triangle edges and then to the interior point. This is a
16 standard technique in numerical surface modeling for mapping applications. Along the
17 edge of a triangle the z-values are interpolated as a linear combination of the projected
18 values from the bounding nodes. Each nodes' contribution is modeled mathematically
19 by an equation of the form:

$$20 \quad z = Ax + By + C$$

21 The "A" coefficient is the slope in the x-direction and the "B" coefficient is the
22 slope in the y-direction. If the bounding vertices of the triangle are "1" and "2", then the
23 z-value anywhere in between the bounding values is given by:

$$24 \quad z = (1-t) z_1 + t z_2,$$

25 where z_1 and z_2 are vertex z-values and "t" is the fraction of the distance between points
26 "1" and "2" such that $0 \leq t \leq 1$. Similarly, the z-value at an interior point is linearly
27 projected from the values on the edges. Much more sophisticated interpolation schemes

1 might be used in place of the above. In practice, with well defined data-sets such as those
2 in use for mapping green surfaces, there is little to be gained from the use of more
3 complicated models.

4 Prior to computing the golf ball putt trajectories 111 on a green 100, the location
5 of the cup 101 is input into the database 200. In addition, the speed of the green 100 must
6 be known in order to determine the coefficient of friction to use during the trajectory
7 computations. The green speed is specified in terms of a Stimpmeter value for the green
8 100. A Stimpmeter is an extruded aluminum stake, 36 inches long, with a V-shaped
9 groove extending along its entire length. It has a notch 30 inches from the tapered end,
10 which rests on the ground. The notch holds a golf ball and as the other, non-tapered end
11 is slowly lifted, the ball rolls out of the notch and down the grooved bar onto the green
12 100 when the Stimpmeter inclination reaches an angle of about 20 degrees.

13 The USGA's Stimpmeter instruction manual advises users to select a level area
14 on the green 100, at least 10 feet by 10 feet; roll three balls down the Stimpmeter in one
15 direction; and mark their average stopping point. Then roll three more balls in the
16 opposite direction, and mark their average stopping point. The two distances are then
17 measured and their average distance, measured in feet and inches, is known as the
18 Stimpmeter value or speed for that green 100.

19 This distance value may be converted into a frictional deceleration coefficient by
20 the application of a physics equation of motion relating velocity after traveling a given
21 distance to initial velocity and acceleration:

$$22 \quad v^2 = v_0^2 - 2fx$$

23 where, v_0 is the initial velocity,

24 'x' is the distance traveled, and

25 'f' is the deceleration coefficient with the minus sign chosen to make f positive.

26 Letting 'x' be the Stimpmeter distance and v_0 be the velocity as the ball leaves the

1 Stimpmeter, then $v = 0$ at the Stimpmeter distance:

2
$$f = v_0^2/2x.$$

3 In the next operation 604, the parameters that control the start of computation are
4 input. The ball coordinates are specified, and the step size and initial angle are set. Step
5 size refers to the distance that the ball is assumed to travel on each computational cycle.
6 Typically, this would be the same size as the average point-to-point data spacing as this
7 is the real resolution limit of variability within the data. The initial angle is the angle
8 measured from the horizontal that opens positively in a counterclockwise direction. This
9 angle is used in the initial partitioning of velocities and accelerations into x and y-
10 components.

11 The initial step size and initial velocity values are used to set an internal time increment
12 for the initial step computation. This time increment is simply the step size divided by
13 the initial velocity. This time increment can be used throughout the computations or it
14 can be computed for each step.

15 The choice of an initial velocity 605 used for calculating the trajectory 111 of the
16 ball to the cup 101 is computed from the same equation used to compute the deceleration
17 coefficient:

18
$$v^2 = v_0^2 - 2fx$$

19 Here 'x' is the distance from ball to cup plus about 18 inches as the desired radius about
20 the cup; 'v' will be zero; and the equation is solved for v_0 , i.e.,

21
$$v_0 = (2fx)^{1/2}$$

22 The next step 606, takes the direction angle 604 and the initial velocity 605, and
23 sets up the x and y-components for computation. At this point the numerical green
24 surface 602 will be queried for the elevation and the x, y-slope values. Utilizing the slope
25 components, the gravitational and frictional components are initialized. The final

1 operation calculates the x,y-distances that the ball will move for the first step. The time
2 increment that it takes to move the ball through this distance is also computed.

3 The next step 607 is calculated utilizing the values computed at the initial value
4 stage or from a previous iteration step, by updating velocity components, direction of
5 motion angles, ball x,y coordinates, elevations and slopes, gravitational acceleration
6 components and new distance and time (if dynamic) elements. At each iteration, the
7 velocity value from the preceding step becomes the current v_0 . The updated velocity is
8 computed from:

$$9 \quad v = v_0 + a t,$$

10 where:

11 a is the acceleration term combining gravity and friction effects, and

12 t is the current time element for this step (may be constant or dynamic).

13 This equation is applied separately for both x and y-components. The direction of motion
14 angle 604 is re-computed from the updated velocity components. The distance that the
15 ball travels (d) during this time is computed from:

$$16 \quad d = v_0 t + 1/2 a t^2$$

17 This equation is applied to both the x and y-components after which the ball coordinates
18 are updated.

19 At the new x,y-coordinates, a new elevation value and new x,y-derivatives
20 (slopes) are computed. Using the slope values, the gravitational acceleration components
21 are re-computed for each direction. New distance components to be used in the next
22 iteration are computed. If the time element is dynamic, it too is computed. If both x and
23 y-distance elements are less than those computed for the specified time element, the ball
24 is assumed to have come to rest and the distance elements are updated accordingly and
25 status flags are set accordingly.

26 When the ball has come to rest 608, it is necessary to determine if it fell short 609

1 of the cup 101 location, or rolled too far past the cup 101. Using the distance at
2 termination of the ball motion 608 to cup 101, the initial velocity 605 is modified 610 by:

$$3 \quad v_{\text{new}}^2/v_{\text{old}}^2 = d_{\text{old}}/d_{\text{new}},$$

4 where v and d are velocity and distance respectively. The subscript "old" refers to the
5 previous iteration, and the subscript "new" is the value to be used in the next iteration.

6 If the ball rest position 608 at the end of computations is too far to one side or the
7 other of the cup 101, then the angle 611 is adjusted 612 in fixed increments 613 (e.g., 10-
8 degrees) until the ball position is on the opposite side of the cup 101 from the previous
9 iteration. At this point, the angular increment 612 is halved and added or decremented
10 to the last value such that the resulting angle falls in-between the previous pair of angles.
11 This iterative process continues until the ball motion terminates 614 within the required
12 distance of the cup 101.

13 To facilitate the slope computations, an integral part of the numerical processing
14 used to build the numerical surface model of the green 100 is a triangulation of the point
15 set.

$$16 \quad z = Ax + By + C$$

17 The "A" coefficient is the slope in the x-direction and the "B" coefficient is the
18 slope in the y-direction. If the bounding vertices of the triangle are "1" and "2", then the
19 z-value anywhere in between the bounding values is given by:

$$20 \quad z = (1-t) z_1 + t z_2$$

21 where z_1 and z_2 are vertex z-values. Then "t" is the fraction of the distance between points
22 "1" and "2" such that $0 \leq t \leq 1$. Similarly, the z-value at an interior point is linearly
23 projected from the values on the edges.

24 The force of the wind and the "grain" or tilted growth pattern of the grass on a
25 green may each possibly have an effect on the trajectory 111 of a moving golf ball. If
26 there is a substantial wind present, the force and direction can be established with an

1 anemometer and a wind or weather vane which are in communication with database 200.
2 A wind effect calculation can be included in the equations of motion discussed above if
3 windy conditions prevail. The effect of grain on grass which has been mowed to a height
4 of 9 or 10/1000 ths of an inch is still being debated. According to personal
5 communications with two United States Golf Association Regional Agronomists, the
6 effect of grain is negligible on grass mowed to this specification for a Professional Golf
7 Tournament. Therefore, the grass grain effect has not been incorporated into the
8 equations of motion set out above.

9 As previously discussed, the topographic database 200 allows for a variety of
10 graphics overlay displays to be utilized in showing the possibilities/limitations of the
11 trajectories 111 of the putts open to the golfers. Contours 106 of the green 100 may be
12 displayed for easy visualization of the variability of the televised green 100 surface.
13 Either superimposed on the contours 106, or by themselves, the putting trajectories 111
14 may be displayed as an overlay on the TV image. Full perspective views may be
15 displayed of all overlay data to facilitate registration with a television camera at the site.

16 Referring now to FIG.8, generally the production center is housed in a truck or
17 trailer parked somewhere on the golf course property. The heart of the production center
18 is processor 200. The processor 200 can be a powerful computer such as an Onyx 2
19 computer from Silicon Graphics. Processors 156, which are associated with the broadcast
20 cameras 140 on each televised green 100, can be an Intel Pentium processor, or its
21 equivalent, with supporting electronics. Processor 156 has memory and a disk drive to
22 store data and software. The processor 156 is in communication with pan-tilt electronics
23 150; analog to digital converter 154; and with the production center via signal BC-1.
24 There are however, other suitable off-the-shelf processors or combinations of processors
25 which can perform the necessary functions of this invention. Each of these will have
26 separate compute and graphics subsystems. A subsystem is defined as one of many
27 functional components of a computer *i.e.*, memory unit, central processing unit and
28 input/output unit. The compute and graphics subsystems are important to this invention.
29 The compute subsystems can scale up to multiple processors and the graphics can scale

1 up to multiple graphics subsystems. This scalability allows 3-D graphics, image
2 processing and live video to be calculated, manipulated and displayed in real time.

3 The flow diagram, shown in FIG. 7, illustrates the overall architecture of the main
4 processor software 200 which supports the present invention. It is made up of the
5 following software sections: (1) Initialization Database 200-a, (2) Data Input 200-b, (3)
6 Processing Flow 200-c, and (4) Data Output 200-d.

7 The software 200 retrieves data from the database 200-a containing golf green
8 topographic contours 106 and stored television images which can be processed into a 3-D
9 graphic display and merged with a live video feed of a golf match or tournament. In this
10 process, the trajectory is calculated for the proper path 111 for a golf ball to travel across
11 the green 100, in order for it to roll into the golf cup 101 or to come to rest within 18
12 inches of the cup 101.

13 The Initialization Database 200-a contains the x,y,z contour values 106 and the
14 stored television images which represent each green 100 on the golf course. This function
15 positions the software 200 to the correct data in the Database 200-a and synchronizes and
16 registers the Database 200-a to match the appropriate live video broadcast.

17 The Data Input function 200-b retrieves the x,y,z values which are to be displayed
18 from the Database 200-a as contours 106. The software 200 then reads the contours 106
19 and green images for processing. The retrieval continues in an iterative manner until all
20 data has been processed for the appropriate green 100.

21 The Processing Flow function 200-c calculates the orientation, tilt, zoom and pan
22 of the broadcast cameras; performs edge matching of the outline of the contoured green
23 100 with the televised TV image of the outline of the selected golf green 100, using well-
24 known pattern recognition techniques; merges these data; and calculates the best ball path
25 trajectories 111 using the equations of motion presented previously. The Processing Flow
26 function 200-c includes the determination of the correct data orientation necessary to
27 match the desired camera's field of view 115. This function 200-c produces a composite

1 of the contours 106 and images of the green in the perspective required by the changing
2 camera positions.

3 The Output function 200-d merges the contours 106, images and best possible
4 putt display 111 with the live video from the broadcast camera. A digitizer tablet, mouse,
5 or pointer, mapped directly to a grid representing the golf green 100, is used to
6 communicate and register the golf balls 102, 103, 104, and 105; the golf cup 101; and the
7 shoulder-held camera 114 locations. Alternatively, the x,y,z coordinates of the golf balls
8 102, 103, 104, and 105, the golf cup 101, the platform camera 113, and the shoulder-held
9 camera 114 can be determined through the use of laser surveying equipment. These
10 locations are used to orient the viewing angle and to calculate a best possible path 111
11 for putting the golf ball into the golf cup 101. This function merges all of the data together
12 and seamlessly displays it, along with the golfers, on the real-time television broadcast.

13 FIG.8 is a block diagram of the hardware components that make up the invention.
14 These components are generally located in a production center situated on the golf
15 property being televised but could be located at other suitable locations. Broadcast
16 camera 140 records frames of video coverage which are forwarded to the production
17 center. They are identified as signal BC-1. This camera 140 has a zoom lens and a
18 zoom/focus sensor 152, known collectively as a "zoom sensor", connected to broadcast
19 camera 140, which can sense the zoom in the camera and the focal distance of the camera
20 lens. The analog output of sensor 152 is sent to an analog to digital converter 154, which
21 converts the analog signal to a digital signal, and transmits the converted signal to
22 processor 156. If a zoom sensor with a digital output is used as an alternative, there
23 would be no need for the analog to digital converter 154.

24 Broadcast camera 140 is mounted on tripod 144 and has attached pan and tilt
25 heads which allow broadcast camera 140 to pan and tilt. Pan sensor 146 and tilt sensor
26 148 are attached to tripod 144 and both are in communication with pan-tilt electronics
27 150. These units can alternatively be built into broadcast camera 140. In either case, pan
28 sensor 146, tilt sensor 148, and zoom sensor 152 are considered to be coupled to

1 broadcast camera 140 for the reason that they can sense the pan, tilt, and zoom of the
2 broadcast camera 140.

3 Pan/tilt electronics 150 receives the output of pan sensor 146 and tilt sensor 148,
4 converts the output to a digital signal representing those sensors and transmits the digital
5 signal to processor 156. The pan, tilt, and zoom sensors are used to determine the field
6 of view 115 of the broadcast camera 140, and can therefore be considered as field of view
7 115 sensors.

8 As a result of the pan, tilt, and zoom of the broadcast camera 140, the stored
9 outline image of the green 100 is distorted and must be rotated, magnified or reduced,
10 twisted, etc., as required, to match the changed perspective of the live video image of the
11 green 100, so that the two images can be registered. Processor 200 can determine the
12 proper orientation of the stored image of the green outline based upon the field of view
13 data and/or may use pattern recognition techniques to achieve registration. By knowing
14 where a platform camera is located, and the pan, tilt, and zoom of the camera, the
15 computer can be programmed to determine how to configure the stored image of the
16 green 100 to achieve registration with the video image observed by the broadcast camera.

17 Once the two images are registered, the computer will continuously compare the
18 images, such that when the players walk onto the green 100, the images can be subtracted
19 to define the occlusions i.e., the players images. The occlusions will be removed from the
20 video feed and stored in database 200. The contours 106 will then be displayed over the
21 green image and the occluded images retrieved and superimposed onto the contoured
22 green and the combined video feed broadcast to the television audience. This processing
23 of the data should result in a delay of less than one second and will air as live television.

24 Broadcasters use many broadcast cameras 140 on a golf course to televise a
25 tournament event. Processor 200 is in communication with video control 202 and
26 multiplexor 206. The video signals from the various cameras are sent to video control
27 202 which is used to select one broadcast camera 140 for transmission to the viewers.
28 Video control 202 may include a plurality of monitors to have one for each video signal

1 and will have a selection circuit which will enable a Director to monitor the various video
2 signals and choose the signal to broadcast. The choice would be communicated to the
3 selection circuit which selects one camera signal to broadcast and the selected choice is
4 also communicated to processor 200, and multiplexer 206 via signal 208. The selected
5 video signal is sent to delay 210 and processor 200 via analog to digital converter 212.
6 There would be no need for a analog to digital converter 212, if the broadcast camera has
7 digital capability.

8 The output of delay 210 is sent to video modification unit 214. The purpose for
9 delay 210 is to delay the broadcast signal a fixed number of frames to provide time for
10 processor 200 to receive data, determine the position of the green 100 in the frame of
11 video and to prepare the enhancements required to display the contours 106 and the ball
12 trajectories 111 onto the real-time video broadcast signal. The video picture is delayed
13 a small number of frames, however since a ten frame delay is the equivalent of one-third
14 of a second, and since it does not accumulate, the television signal is still considered to
15 be a live signal.

16 Multiplexer 206 receives signals from the processors at each of the camera
17 locations. For example, each of the processor signals, such as signal CB-1 are associated
18 with a broadcast camera 140. The Director will communicate his choice of camera
19 signals to be broadcast through the selection circuit to video control 202 which will relay
20 the choice to multiplexer 206 so multiplexer 206 can send the selection to processor 200.
21 The signal sent by multiplexer 206 to processor 200 includes the information from the
22 field of view sensors which enable the processor to determine the cameras perspective
23 and allows a presentation of the contour data 106 and ball trajectories 111 in the proper
24 perspective. On a specific green 100, processor 156 can calculate the field of view 115
25 and relay the information, via multiplexer 206, to processor 200. Alternatively, processor
26 200 can receive the data via multiplexer 206 and determine the field of view 115.

27 Processor 200 is connected to video modification unit 214, and the output of unit
28 214 is designated as signal 226 and is the video signal which will be broadcast. This

1 signal can be broadcast as is, or it can be sent for modification or recording to other
2 hardware. Video modification unit 214 modifies the video signal from delay 210 with the
3 data/signal from processor 200. The type of modification of the broadcast signal will vary
4 depending upon the desired graphic results.

5 An alternative embodiment of this invention would be the broadcast of a televised
6 signal which would split the TV screen to allow a real-time view of a players putt to be
7 shown on one side, or at the top or bottom of the TV screen, while the image of the same
8 green 100, which has been retrieved from the database, would be shown on the other
9 portion of the screen, minus the golfer whose turn it is to putt. This remaining portion of
10 the TV screen would present the contours 106, the players golf ball position, the position
11 of the golf cup 101, and the trajectory 111 of the putt required for the ball to go into the
12 cup 101 or to come to rest within 18 inches of the cup 101. This embodiment would
13 enable the viewers to observe both the players putt on the real-time portion of the screen,
14 and the contour 106 of the green 100 and the trajectory 111 required for this particular
15 putt to be successful on the other portion of the screen. Some of the advantages of this
16 embodiment would be the substantial reduction in computer power required to implement
17 the presentation and the ability to give the viewers an interesting view of the players putt
18 from a lateral perspective when there is no shoulder-held camera 114 in position behind
19 the player to show the preferred in-line view of the putt.

20 Another embodiment of the present invention, would be the use of video tapes of
21 the greens 100 on golf courses throughout the world, as a teaching aid in reading the
22 break of a putt and/or to become familiar with the slopes of the greens 100 of a particular
23 course before playing the course. Additionally, a black and white or colored version of
24 the greens contours 106 could be published in a binder so that a player could carry the
25 binder with them on the course to aid them in reading the trajectory 111 of their putts.
26 Another useful embodiment would be the presentation of the greens 100 on a hand-held
27 optical device with a screen on which the player could bring up a contoured image of the
28 green being played. This would assist them in reading the slopes of the green and
29 improving their selection of the trajectory 111 of the putt, and should result in a dramatic

1 improvement in their putting ability. The contours 106 could be graphically presented in
2 any selected color and contour line symbol. When the player touched the screen with a
3 pointer at the approximate location of their golf ball, the trajectory of their line would
4 appear on the screen to assist them in reading the putt.

5 The foregoing detailed description of the invention has been presented for the
6 purposes of illustration and description. It is not intended to limit the invention to the
7 exact form disclosed, and obviously many modifications and variations are possible
8 through the use of the above teachings by persons skilled in the art.

1 We claim:

2 1. A system for television broadcasting of golf matches, comprising:

3 means for obtaining and inputting to a system control computer detailed
4 topographic measurement data of a selected golf green;

5 means for generating, in response to said topographic data, golf green
6 contours on a selected interval on said selected green;

7 means for generating a real-time live television image of play on said
8 selected green;

9 means for registering from said real-time television image, rest positions
10 of golf balls on said selected green;

11 means for processing an equation of motion for a golf ball registered on
12 said selected green to obtain an optimal trajectory to an approximate golf
13 cup location on said selected green; and

14 means for combining said real-time image and said trajectory into a single
15 television image for television broadcast in real-time.

16 2. The system of Claim 1 wherein said means for processing an equation of
17 motion includes means for determining the influence on said trajectory of gravity, green
18 contours, and friction.

19 3. The system of Claim 2 wherein said means for processing an equation of
20 motion further includes means for determining the influence on said trajectory of wind.

21 4. The system of Claim 1 wherein said means for combining said real-time image
22 and said trajectory into a single television image includes means for projecting said golf
23 green contour data onto said real-time television image for broadcast.

24 5. The system of Claim 4 wherein said means for projecting golf green contours
25 onto said real-time television image further includes means for allowing golf players and

1 other human beings to occlude said trajectory and contour data in said real-time
2 television image.

3 6. In a system for the live television broadcasting of golf matches, the
4 improvement comprising:

5 means for inputting to a system control computer detailed topographic
6 measurement data of a selected golf green; and

7 means for generating in response to such topographic data, contours on
8 a selected interval on said selected green.

9 7. The system improvement of Claim 6, and further including:

10 means for superimposing on a real-time television camera image,
11 projections of said camera image, and projections of said contours on said
12 selected green.

13 8. In a system for the live television broadcast of golf matches, the improvement
14 comprising:

15 means for processing an equation of motion of a golf ball on said selected
16 green, in response to said contours, to derive a trajectory.

17 9. The system of Claim 8, and further including:

18 means for combining a display image of said trajectory and a real-time
19 live television broadcast image on said selected green into a single
20 television image for live broadcasting.

21 10. The system improvement of Claim 9, and further including:

22 means for processing said equation of motion to derive a trajectory further
23 includes the influence of frictional forces and wind forces on said
24 trajectory of a golf ball.

25 11. The system of Claim 1, and further comprising:

1 means for registering said topographic data with said television image
2 using a feature adjacent said golf green.

3 12. The system of Claim 11, wherein said feature comprises a sprinkler head.

4 13. The system of Claim 11, wherein said feature comprises an edge of said
5 green.

6 14. The system according to Claim 1, and further comprising:

7 means for annotating the real-time live television image.

8 15. A process for use in television broadcasting of golf matches, comprising the
9 steps of:

10 (a) obtaining and inputting to a system control computer detailed
11 topographic measurement data of a selected golf green;

12 (b) generating, in response to said topographic data, golf green contours
13 on a selected interval on said selected green;

14 (c) generating at least one real-time live television image of golf play on
15 said selected green;

16 (d) registering from said real-time television image rest positions of golf
17 balls on said selected green;

18 (e) processing an equation of motion of at least one registered golf ball to
19 obtain an optimal trajectory to an approximate golf cup location on said
20 selected green.

21 16. The process of Claim 15 and further including the step of:

22 combining said real-time image and said trajectory into a single television
23 image suitable for broadcast.

- 1 17. The method of Claim 16, wherein all of the steps are performed in real- time.
- 2 18. The method of Claim 15, wherein the step of processing an equation of
- 3 . motion includes the step of determining the influence on said trajectory
- 4 of at least: gravity, green speed, and green surface contours.
- 5 19. The method of Claim 18, wherein the step of determining the influence on
- 6 said trajectory includes at least that of friction or green Stimpmeter speed.
- 7 20. The method of Claim 19, wherein the step of determining the influence on
- 8 said trajectory includes at least that of wind.

+

FIG. 1

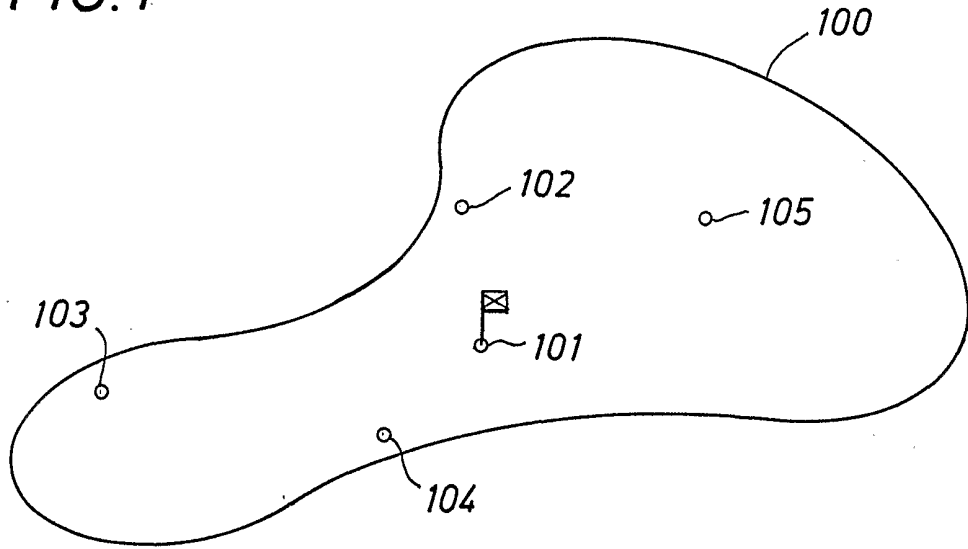
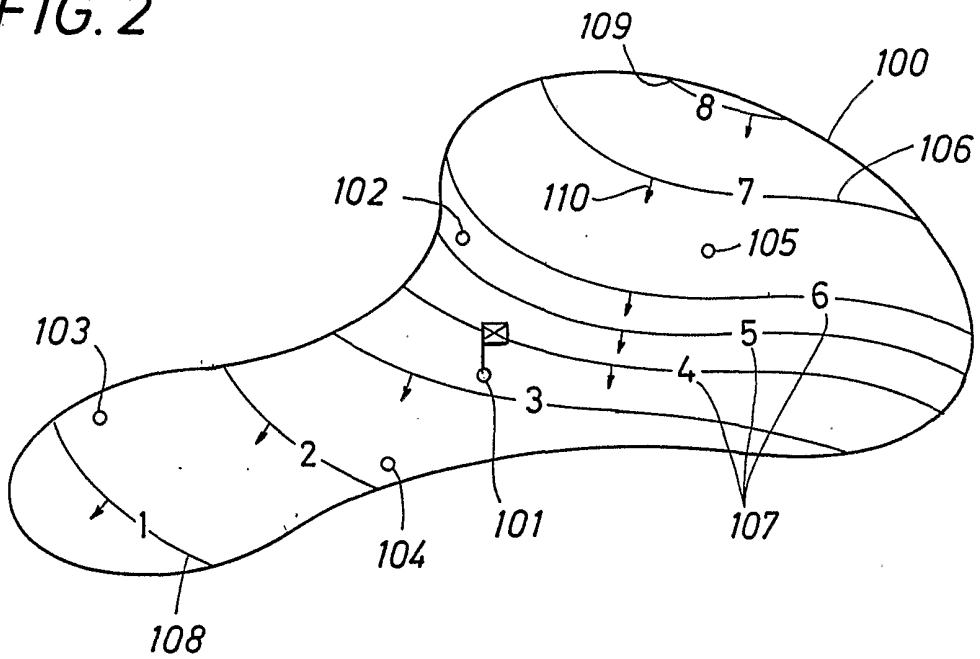


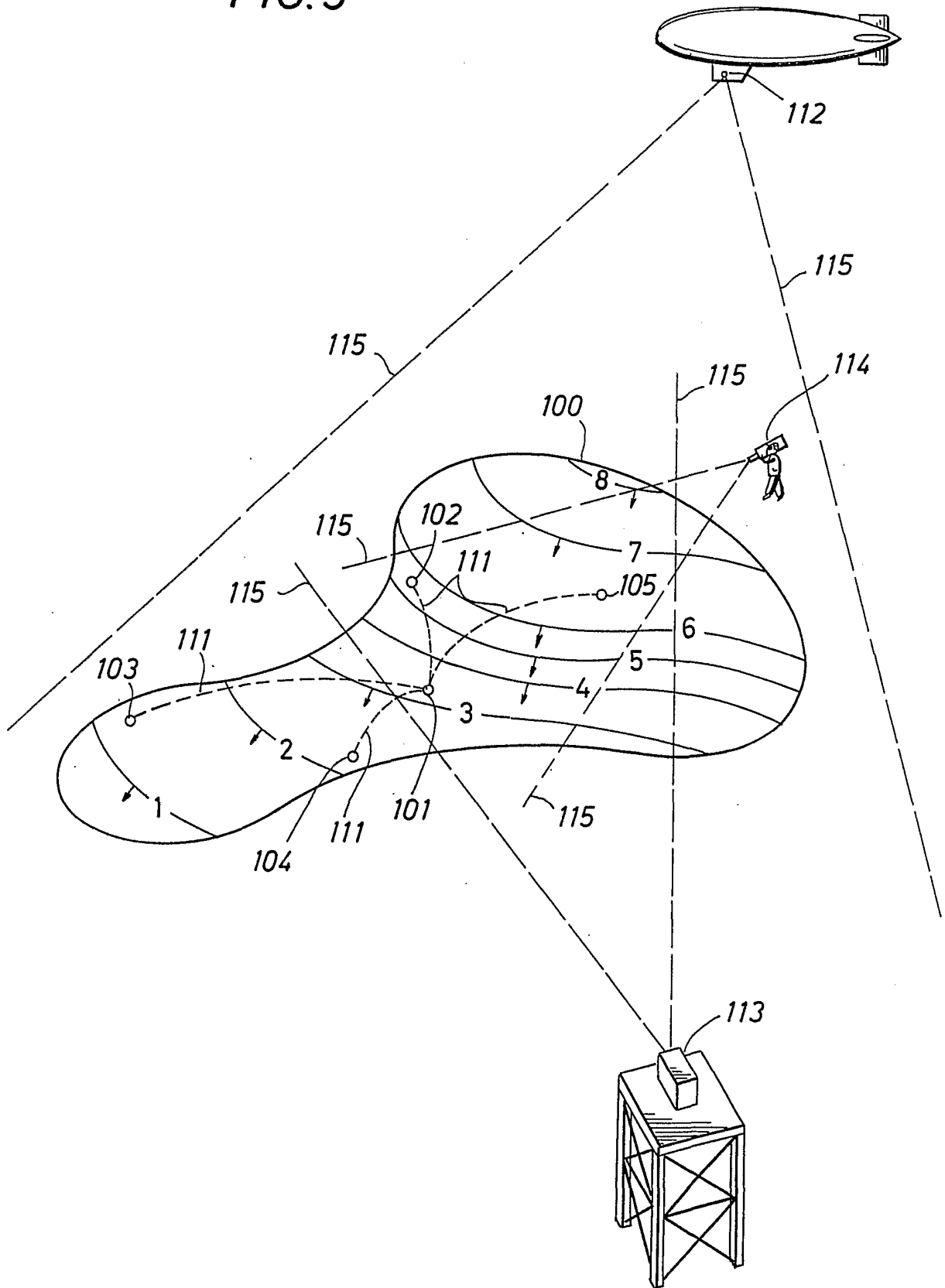
FIG. 2



+

+

FIG. 3



+

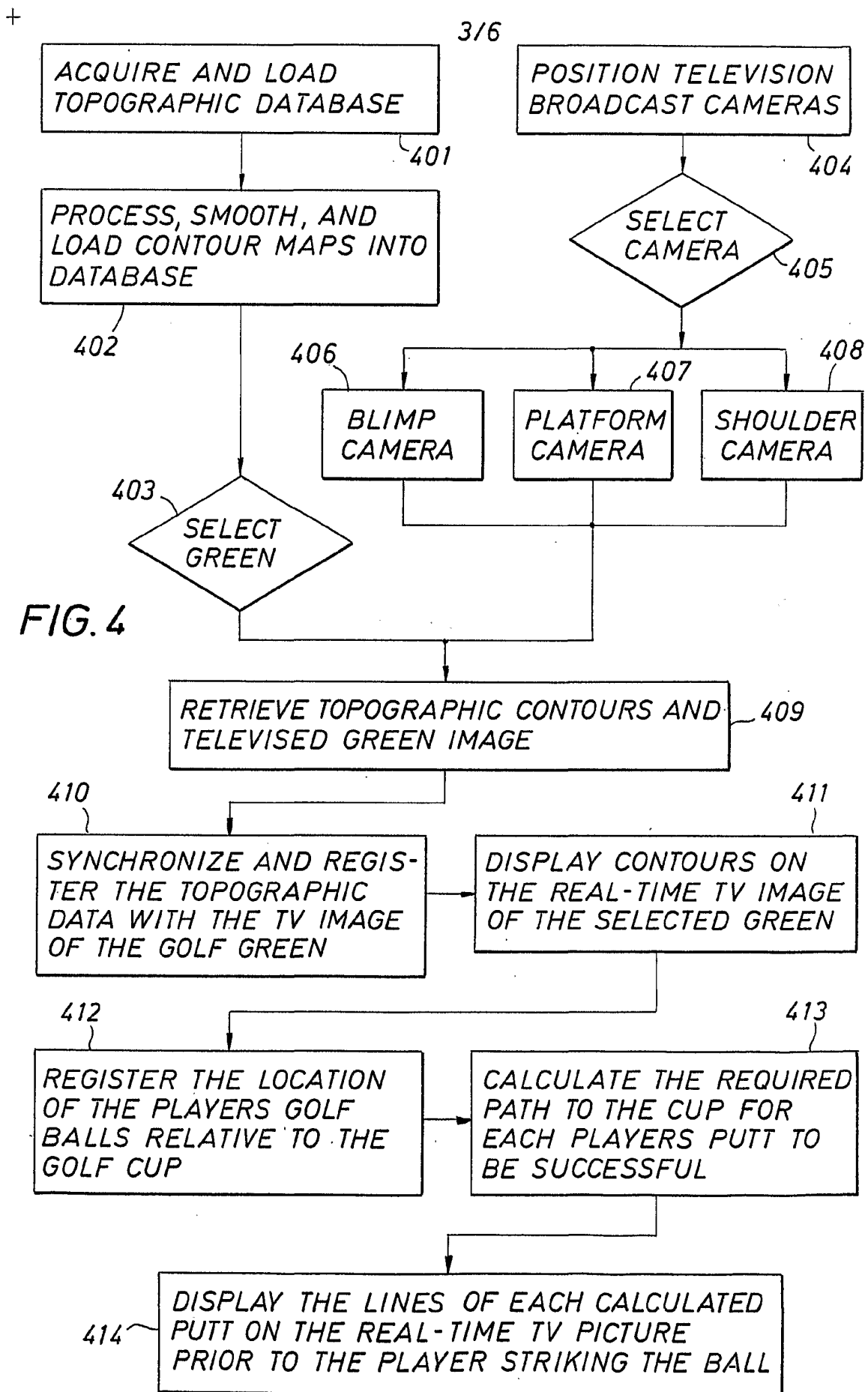
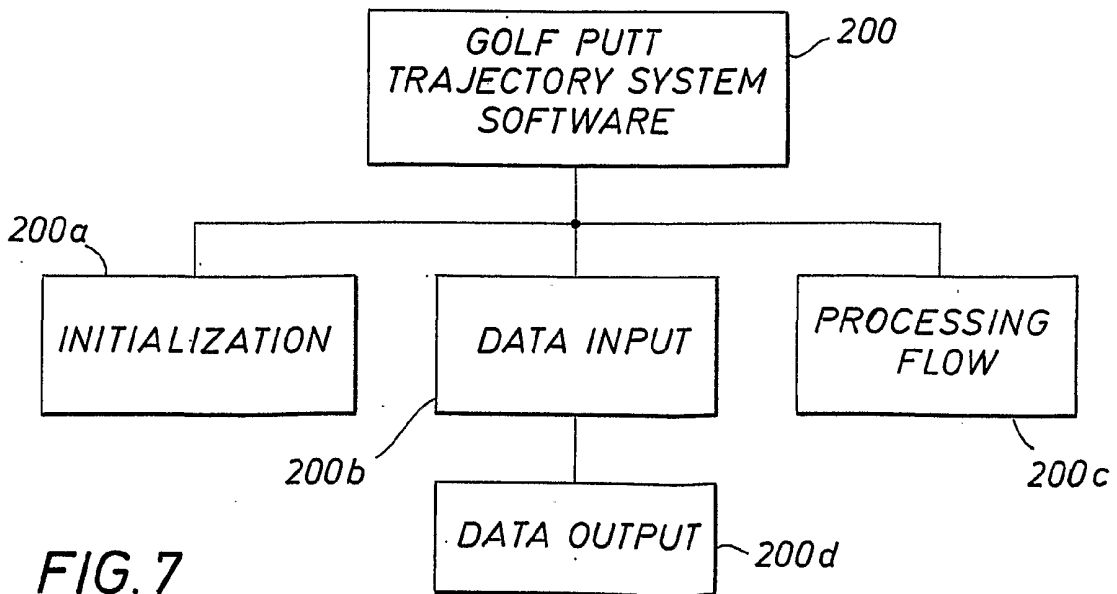
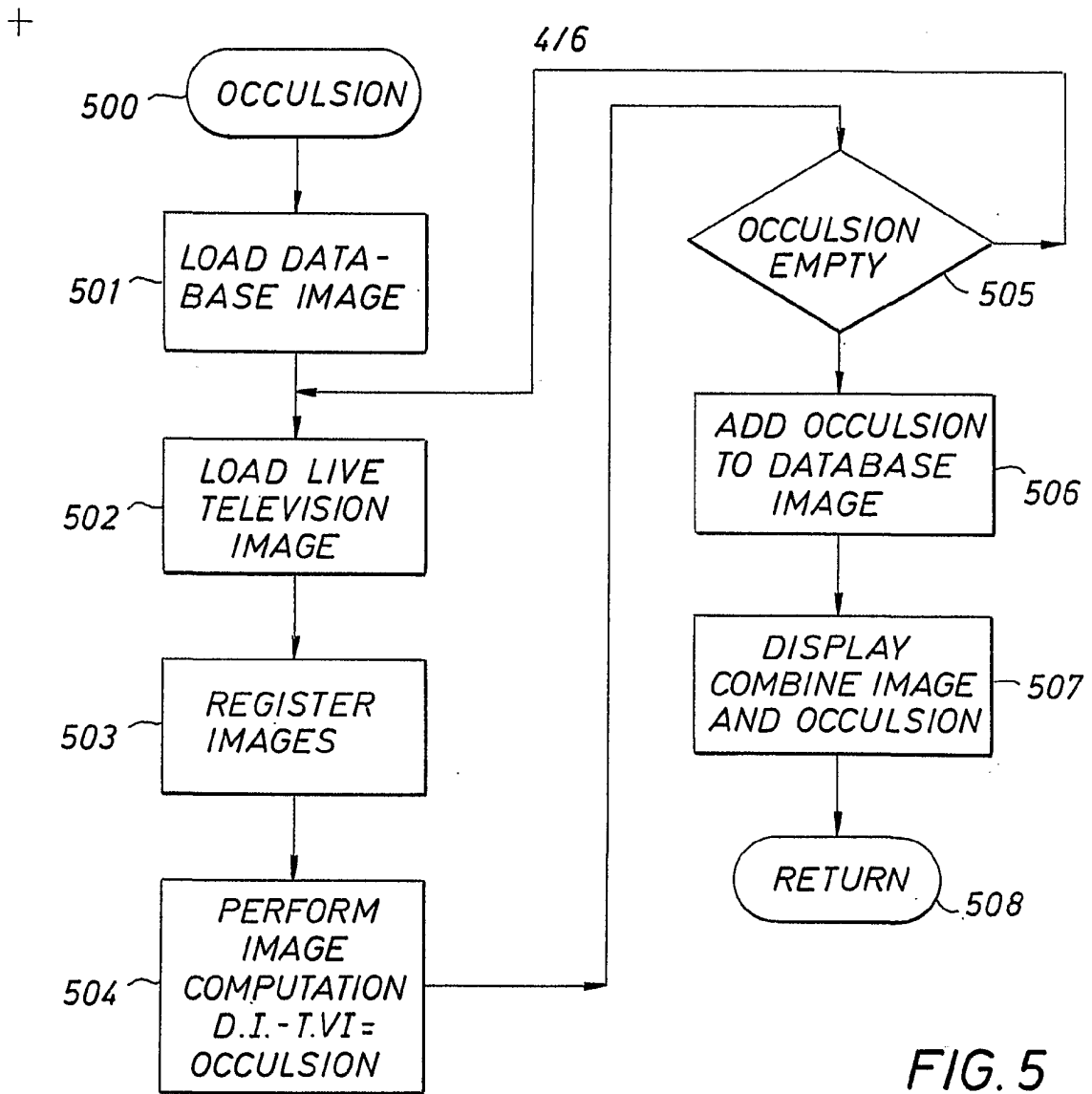


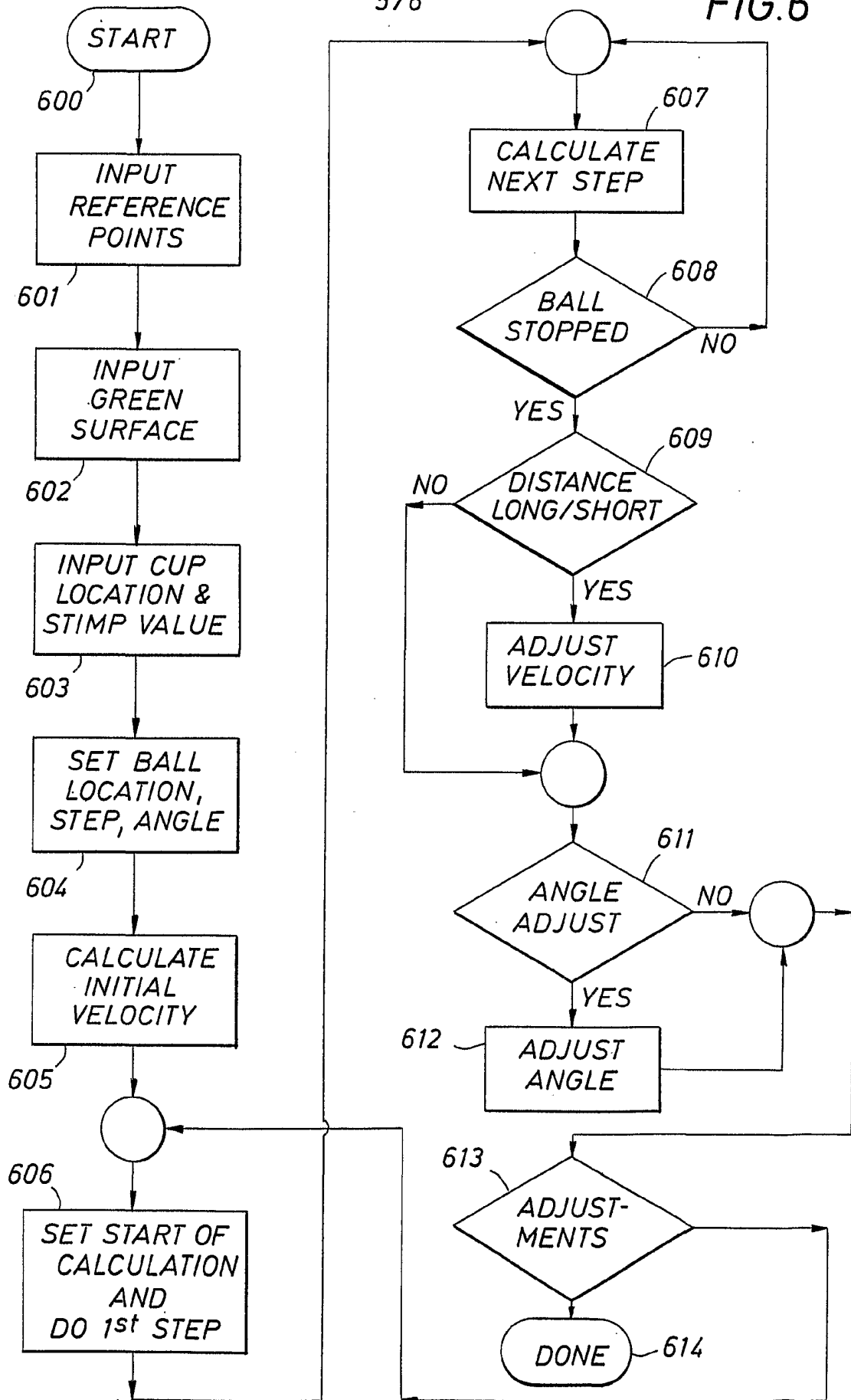
FIG. 4



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5/6

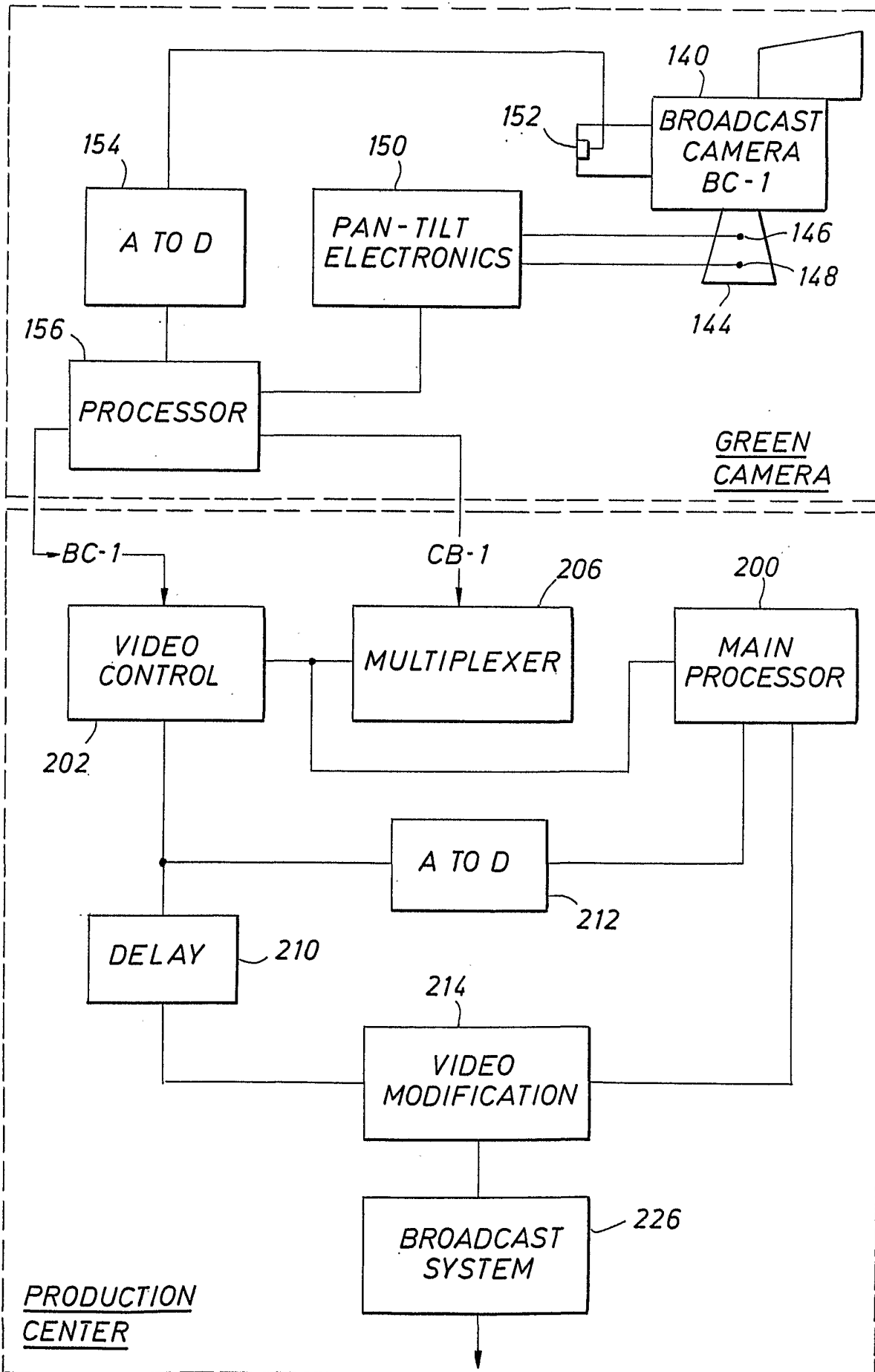
FIG. 6



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FIG. 8



INTERNATIONAL SEARCH REPORT

Int. ional Application No
PCT/US 01/26618

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04N5/262 A63B69/36

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 7 H04N A63B G06T

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, A P, X	WO 01 14021 A (ROBINSON LEE D) 1 March 2001 (2001-03-01) page 10, line 29 -page 11, line 7 page 15, line 9 -page 18, line 12 page 21, line 16 -page 22, line 3 page 24, line 26 -page 5, line 4 ---	1, 4, 5, 15, 19 6, 7
A	US 4 975 770 A (TROXELL JAMES D) 4 December 1990 (1990-12-04) column 3, line 4 -column 5, line 17 ----- -/--	1, 6, 15

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

° Special categories of cited documents :

- *A* document defining the general state of the art which is not considered to be of particular relevance
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Date of the actual completion of the international search

20 February 2002

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	LORENSEN W E ET AL: "GOLF GREEN VISUALIZATION" IEEE COMPUTER GRAPHICS AND APPLICATIONS, IEEE INC. NEW YORK, US, vol. 12, no. 4, 1 July 1992 (1992-07-01), pages 35-44, XP000281902 ISSN: 0272-1716 page 35, line 15 -page 39, right-hand column, line 38 page 44, left-hand column, line 30 - line 55	1,2, 8-10,15, 18,19
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