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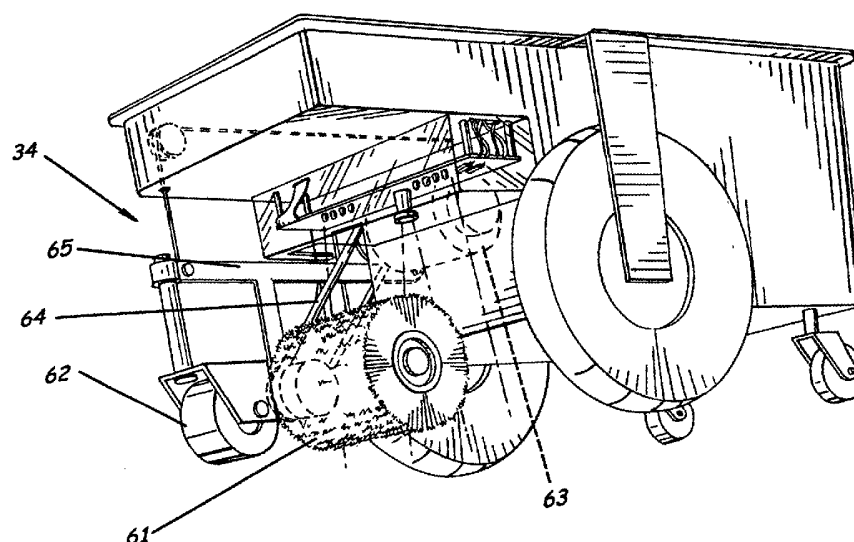
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(54) Title: APPARATUS AND METHODS FOR CLEANING LINES ON A PLAYING SURFACE



(57) Abstract: An apparatus and method for clearing a playing surface are provided. The apparatus preferably includes a chassis or frame, a sensor connected to the chassis to sense a location of a line on a playing surface that needs to be cleaned, and a drive connected to the chassis to drive the chassis in a selected direction of travel. The apparatus also preferably includes a controller connected to the chassis, in communication with the drive, and responsive to the sensor to control the drive to thereby direct the chassis to move along the line that needs to be cleaned in the selected direction of travel and a cleaning device connected to the chassis to clean the line with the chassis is being driven along the line. Associated software is provided as well.



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APPARATUS AND METHODS FOR CLEANING LINES ON A PLAYING SURFACE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This is a non-provisional patent application which claims the
5 priority of provisional patent application U.S. Serial No. 60/314,933, filed
August 24, 2001, and titled "Automatic Propulsion, Navigation and Control of
Cleaning Device for Tennis Court Lines," which is incorporated herein by
reference in its entirety.

BACKGROUND OF THE INVENTION10 **1. Field of the Invention**

[0002] The present invention relates to the surface maintenance and
treatment industries in general and, in particular, to an apparatus and methods
for cleaning lines on a playing surface.

2. Description of the Related Art

15 [0003] A tennis court is a flat surface defined by multiple boundary
lines, namely, sidelines, baselines, service lines, and center lines. The double's
sidelines, single's sidelines and baselines define the backcourts. The single's
sidelines and service lines define the service courts. The center lines divide the
service courts. For a hard court, the above-mentioned boundary lines are
20 typically drawn beforehand on a sheet of plastic pasted over a concrete base.
For a clay or lawn court, the above-mentioned boundary lines are typically
prepared by fixing white tape on a playing surface via tacks.

[0004] In general, a clay-surface tennis court or clay court requires daily
maintenance in the form of smoothing and watering. The smoothing process is
25 typically performed by dragging a broom or brush across the entire surface of
the clay court for smoothing out the loose material on the surface of the clay
court. After the smoothing process, the boundary lines on the clay court are
usually covered with clay dust. As such, the boundary lines must be cleared of

the clay dust before watering and/or before any serious play can be conducted on the clay court. Also, after several games have been played on the clay court, the boundary lines may again be covered by clay dust that necessitates cleaning. Commonly, the cleaning is performed by a person walking a roller
5 brush over all the lines of the clay court, which is very laborious and time-consuming, not to mention tiresome. An example of such a roller brush can be seen in U.S. Patent No. 4,958,400 by Sugita titled "*Line Cleaning Apparatus*." Consequently, it is desirable to provide an apparatus for enhancing the cleaning of boundary lines on a playing surface such as a tennis court.

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SUMMARY OF THE INVENTION

[0005] The present invention advantageously provides an apparatus and methods for enhancing the cleaning of boundary lines on a playing surface which substantially reduces or eliminates the manual labor involved in caring for the playing surface. The present invention also advantageously provides a
15 cleaning apparatus and methods that reduce the time involved in caring for a playing surface. The present invention additionally advantageously provides a cleaning apparatus and methods that sense the presence of a boundary line that needs to be cleaned and directs the cleaning of the line without the need for any substantial manual labor. The present invention still also advantageously
20 provides a cleaning apparatus and methods having familiarity or dimensions of a playing surface, such as a clay-surface tennis court, stored in memory, and directs the cleaning of the boundary lines of the tennis court by sensing the presence of or a location of the boundary lines.

[0006] More particularly, the present invention provides an apparatus for
25 cleaning boundary lines on a playing surface which has a cleaning device, a drive positioned to drive the cleaning device along at least one boundary line of a playing surface, and a controller in communication with the drive and the cleaning device to selectively control the driving of the cleaning device to clean

the at least one boundary line on the playing surface when the drive is driving the cleaning device along the at least one boundary line.

[0007] The present invention also provides an apparatus for cleaning lines on a game playing surface which has a chassis, sensing means connected
5 to the chassis for sensing a location of a line associated with a game playing surface that needs to be cleaned, driving means connected to the chassis for driving the chassis in a selected direction of travel, controlling means connected to the chassis, in communication with the driving means, and responsive to the sensing means for controlling the driving means to thereby
10 direct the chassis to be driven along the line that needs to be cleaned in the selected direction of travel, and a cleaning device connected to the chassis to clean the line when the chassis is being driven along the line.

[0008] The present invention also provides methods of cleaning boundary lines on a playing surface. A method for cleaning boundary lines on
15 a playing surface preferably includes directing a cleaning device to move along boundary lines on a playing surface responsive to a set of programmed directions, and cleaning the boundary lines when the cleaning device is moving along the boundary lines.

[0009] Another method for cleaning boundary lines on a game playing
20 surface preferably includes directing a cleaning device to move along boundary lines on a game playing surface responsive to a set of programmed directions, and selectively positioning a cleaning tool on a boundary line to clean the boundary line as the cleaning device is moving over the boundary line.

[0010] Yet another method for cleaning boundary lines on a game
25 playing surface, which has a first playing surface and a second playing surface separated from each other by a net connected between net a plurality of posts, preferably includes directing a cleaning device to move along boundary lines on the first playing surface responsive to a set of programmed directions, cleaning the boundary lines on the first playing surface as the cleaning device

is moving over the boundary lines on the first playing surface, directing the cleaning device to move around one of the net posts to position the cleaning device on the second playing surface, and a cleaning the boundary lines on the second playing surface as the cleaning device is moving over the boundary
5 lines on the second playing surface.

[0011] The present invention further provides a computer program product residing on a computer usable medium for directing a cleaning device to clean at least one line on a surface. A computer program product preferably includes program code means for directing a cleaning device to move along at
10 least one line of a surface and program code means for cleaning the at least one line on the surface when the cleaning device is moving along the at least one line.

[0012] Another computer program product for cleaning boundary lines on a game playing surface is provided according to the present invention. The
15 computer program product includes program code means for directing a cleaning device to move along boundary lines on a game playing surface responsive to a set of programmed directions and program code means for selectively positioning a cleaning tool on a boundary line to clean the boundary line as the cleaning device is moving over the boundary line.

[0013] Another computer program product for cleaning boundary lines on a game playing surface, which includes a first playing surface and a second playing surface separated from each other by a net connected between a plurality of net posts, is also provided. The computer program product includes
20 program code means for directing a cleaning device to move along boundary lines on the first playing surface responsive to a set of programmed directions, program code means for cleaning the boundary lines on the first playing surface as the cleaning device is moving over the boundary lines on the first playing surface, program code means for directing the cleaning device to move around one of the net posts to position the cleaning device on the second

playing surface, and program code means for cleaning the boundary lines on the second playing surface as the cleaning device is moving over the boundary lines on the second playing surface.

[0014] Accordingly, the present invention advantageously provides a
5 cleaning apparatus and methods which selectively operate a cleaning device when the location or presence of a boundary line is sensed or when the cleaning apparatus determines that a boundary line needs to be cleaned. The present invention further advantageously provides software to enhance the cleaning of a surface such as boundary lines on a tennis court or other selected surface.

10 **BRIEF DESCRIPTION OF THE DRAWINGS**

[0015] Some of the features and advantages of the present invention having been stated, others will become apparent as the description proceeds when taken in conjunction with the accompanying drawings, in which:

[0016] FIG. 1 is an environmental view of a cleaning apparatus being
15 used for cleaning lines on the playing surface of a tennis court according to an embodiment of the present invention;

[0017] FIG. 2 is a perspective view of a cleaning apparatus according to an embodiment of FIG. 1 of the present invention;

[0018] FIG. 3 is a perspective view of a cleaning apparatus according to
20 another embodiment of the present invention;

[0019] FIG. 4 is a perspective view of a cleaning apparatus according to yet another embodiment of the present invention;

[0020] FIG. 5 is a bottom plan view of a cleaning apparatus according to the embodiment of FIG. 3 of the present invention;

25 [0021] FIG. 6 is a side elevational view of a cleaning apparatus according to the embodiment of FIG. 3 of the present invention;

[0022] FIG. 7 is a block diagram of a cleaning apparatus according to an embodiment of the present invention;

[0023] FIG. 8 is a schematic diagram of a line-sensing module within a cleaning apparatus according to an embodiment of the present invention;

[0024] FIG. 9 is a schematic diagram of a propulsion module within the cleaning apparatus according to an embodiment of the present invention;

5 [0025] FIG. 10 is a flowchart illustrating operation of a cleaning apparatus and associated software and methods according to an embodiment of the present invention;

[0026] FIG. 11 is a top plan view of a cleaning route on a tennis court, in accordance with an embodiment of the present invention;

10 [0027] FIG. 12 is a schematic view of a route for a cleaning apparatus to travel around a net post of a tennis court according to the present invention; and

[0028] FIG. 13 is a flow chart of operation of a cleaning apparatus for traveling around a net post of a tennis court according to the present invention.

DETAILED DESCRIPTION

15 [0029] The present invention will now be described more fully with reference to the accompanying drawings. The present invention, however, may be embodied in many different forms and should not be construed as limited to the illustrated embodiments set forth herein. Rather, such embodiments are provided so that the present disclosure will be thorough and complete, and will
20 fully convey the scope of the present invention to those skilled in the art. Like numbers refer to like elements throughout, incremental hundred numbers, if used, indicates similar elements in alternative embodiments.

[0030] FIG. 1 illustrates a cleaning apparatus 30 cleaning boundary lines on a surface such as a tennis court 20 in accordance with an embodiment of the
25 present invention. As shown, a tennis court 20 is a flat surface defined by single's sidelines 21a-21b, double's sidelines 22a-22b, baselines 23a-23b, service lines 24a-24b, and center lines 25a-25b. The single's sidelines 21a-21b, the double's sidelines 22a-22b and the baselines 23a-23b define the backcourts. The single's sidelines 21a-21b and the service lines 24a-24b

define the service courts. The center lines **25a-25b** divide the service courts. The baselines **23a** and **23b** include center marks **26a** and **26b**, respectively. The size of a standard single's court is defined as 27 feet by 78 feet, and the size of a standard double's court is defined as 36 feet by 78 feet. The size of a
5 standard service court is defined as 27 feet by 42 feet. As depicted in FIG. 1, a cleaning apparatus **30** for cleaning boundary lines on the tennis court **20** is shown to be cleaning the double's sideline **22b**. Preferably, the tennis court **20** has a clay or fast dry surface, or any of the other variety of clay-like surfaces sometimes referred to as "clay" or "soft," including those that may be referred
10 to by their trademarked or brand names such as Har-Tru or Fast-Dri, and require routine maintenance that generally involves smoothing and sweeping the surface and brushing the lines.

[0031] FIGS. 2-7 illustrate a cleaning apparatus **30**, in accordance with three different embodiments of the present invention. As shown, the cleaning
15 apparatus **30, 130, 230** includes a main frame or chassis **35, 135, 235** sensing means, such as provided by a line-sensing module **31, 131, 231**, connected to the chassis **35, 135, 235** for sensing a location or presence of a line associated with a surface or a game playing surface that needs to be cleaned, driving means, such as provided by a propulsion or drive module **33, 133, 233**,
20 connected to the chassis **35, 135, 235** for driving the chassis in a selected direction of travel, controlling means, such as provided by a navigation and control module **32, 132, 232**, connected to the chassis **35, 135, 235**, in communication with the driving means, and responsive to the sensing means for controlling the driving means to thereby direct the chassis to be driven
25 along the line that needs to be cleaned in the selected direction of travel, and a cleaning device **34, 134, 234** connected to the chassis **35, 135, 235** to clean the line when the chassis **35, 135, 235** is being driven along the line. The line-sensing module **31** senses various landmarks (such as lines of specific lengths, net posts, line boundaries) on the tennis court **20** via a sensing device such as a

sonar, a radio frequency sensor, a transducer, a camera, a charge coupled device, photo-optical sensors, radar, a laser or by contact. The design, position and orientation of the line-sensing module 31 preferably allow landmarks that are far away from or in close proximity with the cleaning apparatus 30, 130, 5 230 to be sensed. The sense data information obtained by the line-sensing module 31 is communicated to the navigation and control module 42 for the purpose of navigating the movement of the cleaning apparatus 30, 130, 230. After receiving the sense data information from the line-sensing module 31, the navigation and control module 42 determines the position of the cleaning 10 apparatus 30 in relation to the detected landmark on the tennis court 20, and then controls the propulsion module or drive 43 to move to and along a specific boundary line on the tennis court 20. The sensing device is preferably positioned at an elevation higher than the game playing surface and is preferably oriented to capture an image or data in a direction transverse to the 15 game playing surface. The propulsion or drive module 43 includes an energy supply such as a battery or a fuel cell and an appropriate motor (not shown) for driving wheels, treads, rollers, or other devices to assist travel along a surface. In the present embodiment, movements of the cleaning apparatus 30 are assisted by a pair of drive wheels 46 and a swivel wheel 47. The cleaning 20 device 44 is also activated and deactivated as appropriate to clean a boundary line on the tennis court 20 when the cleaning apparatus 30 is moving along the boundary line. The cleaning device 34 can be a brush, a bristle, an air blower, or other cleaning or surface treatment tool as understood by those skilled in the art. The navigation and control module 33 can activate the cleaning device 34 25 for cleaning when the cleaning device 34 is positioned over a portion of the boundary line that needs to be cleaned, or can deactivate the cleaning device 34 otherwise. The exercise of such control over the cleaning device 34 can conserve energy and can minimize the disturbance to the court surface outside of boundary lines.

[0032] FIG. 8 illustrates a line-sensing module 31, in accordance with an embodiment of the present invention. As shown, line-sensing module 31 includes a plurality of or an array of photo diodes such as infrared or IR emitters 41 and a sensing device 42, e.g., an optical sensing device, having a sensor 43 and at least one lens 44 positioned to help focus light onto the sensor 43. Alternative, for example, the infrared emitters 41, can be light emitting diodes (LEDs) as understood by those skilled in the art. The sensing device 42 is positioned for viewing or sensing in a direction transverse to the court surface with its field of view (FOV) centered at a point in the court area where a boundary line, such as a boundary line 45, is located when the cleaning apparatus 30 is being driven along (and optionally cleaning or treating) the boundary line. As shown, for example, the FOV of the sensing device 42 can be perpendicular to the direction of the boundary line 45 and the FOV of the sensing device 42 can be slightly greater than the maximum width of the boundary line 45. The array of emitters 41 illuminates the court area for the camera 42. The purpose of the array of emitters 41 is to always provide a sufficient illumination for the camera 42, independent of the ambient lighting conditions in which the cleaning apparatus 30 are being operated. The sensing device also preferably includes a sensor interface positioned to serially shift out the captured image defined as a plurality of pixels as understood by those skilled in the art. A brightness level of each pixel, for example, can be represented by or correspond to at least one voltage signal received over a controlled period of time as also understood by those skilled in the art.

[0033] As illustrated, preferably, the line-sensing module 31 is enclosed within a shroud 48. The shroud 48 can be an opaque cover, e.g., formed of a plastic material, for protecting the sensing device 42 and other vision aspects from ambient light and/or other light impact. Although an embodiment of the sensing device 42 is optical in nature, it is understood by those skilled in the art that the sensing device 42 can be implemented by acoustical sensing device, an

electro-magnetic or a magnetic sensing device, radio frequency sensing device, a contact sensor and any other through-the-air or contact sensors.

[0034] As perhaps best shown in FIG. 8, an image of the boundary line 45 is directed to the sensor 43 by the lens 44. The sensor 43 is an integrated circuit containing a set of photodiodes positioned in a single line. The linear array of photodiode elements captures the image received through the lens 44. The sensor 43 then serially shifts out the captured image in analog form with the relative voltage of each pixel representing the relative illumination the pixel received over a controlled period of time, *i.e.*, the image integration time. Thus, the sensor 43 captures and sources an analog pixel stream that is in the form of a one-dimensional (linear) image. The line-sensing module 31 can also include a microcontroller (or a microprocessor) 47 to control the integration time of the sensor 43 and to control the shifting of the analog image coming out of the sensor 43. The microcontroller 47 converts the analog image to a digital image for further processing.

[0035] The purpose of the line-sensing module 31 is to determine the lateral displacement of the cleaning apparatus 30 from a boundary line that is being followed. In order to perform such function, the cleaning apparatus 30 has to be able to process the image captured by the line-sensing module 31 and then determines if the boundary line is present, and the position or location of the boundary line in the FOV of the camera 42 if the boundary line is present. The characteristic of a boundary line that allows it to be distinguished from the court surface is the fact that the boundary line is more reflective of the irradiance received than the court surface. With the digital image, the microcontroller 47 can analyze the information in the digital image via a variety of image processing techniques, such as FOV attenuation adjustment as will be understood by those skilled in the art. Successive images are continuously captured and analyzed so that the present lateral position of the

cleaning apparatus **30** with respect to a boundary line being followed can always be known.

[0036] If an area on the tennis court **20** that is being sensed is one over which the cleaning apparatus **30** has already passed, then the boundary lines in that area should be free from loose materials. This fact supports more fidelity in determining whether a sensed area is on the boundary line or not and in fact should allow the line-sensing module **31** to operate correctly even for boundary lines that are completely covered over when cleaning begins. For this reason, the line-sensing module **31** is preferably positioned downstream from the cleaning device **34** (along the direction of travel).

[0037] Given a known initial position and orientation on the tennis court **20**, the cleaning apparatus **30** can determine its current position by factoring in its change in position. The change in position can be calculated by odometric techniques that involve the continuous measurement of dynamic parameters such as wheel rotations and incorporate static parameters such as wheel diameter (or track dimensions). The odometric technique of position determination, however, typically accumulates errors, and the errors need to be corrected when the cleaning apparatus **30** reaches various court landmarks (which can be sensed based on knowledge of the fixed court geometry and knowledge of the approximate position of the cleaning apparatus **30**) such as line intersections at corners and tees (*e.g.*, the intersection of the double's sideline **22b** and the baseline **23a** and the intersection of the service line **24a** and the single's sideline **21b**, respectively).

[0038] At the ends of boundary lines and when traveling between boundary lines, it is sometimes necessary to steer the cleaning device **34** off any boundary line. The navigation and control module **32** includes a line determiner (not shown) positioned to determine whether a boundary line is present based on the captured image from the line-sensing module **31**. This is accomplished in software, for example. The processing of the images that are

captured by the vision system results in a determination of the presence or absence of the line in the camera FOV. This information is communicated to the navigation and control module 32. When the cleaning device 34 is not over the boundary line, the navigation and control module 32 turns the cleaning
5 device 34 off and retracts the cleaning device 34 to avoid disturbing the portions of the tennis court 20 that do not have a boundary line. The boundary lines of the portion of the tennis court 20 on one side of the net can be traversed and cleaned in a fixed order that is programmed into the navigation and control module 32. When those boundary lines are completed, that side of the tennis
10 court 20 is known to be finished. The navigation and control module 32 knows its position when it finishes one side of the tennis court 20. By utilizing a position analyzer (not shown), the navigation and control module 32 knows the relative position of any point across the net on the other side of the tennis court 20 (based on the fixed standard court geometry). The position of the apparatus
15 is known. The point at which cleaning is to begin on the other side of the net is also known. The fixed standard court geometry then defines the relative position of the two points. This information can define a preprogrammed maneuver for moving from the final position on the first half court to the desired starting position on the second half court. This maneuver can be
20 preprogrammed based on the relative position of two points of interest, i.e., final point on the first half court and the starting point on the second half court, respectively. Such information can be used to navigate to any desired point on the other side of the tennis court 20 based on the above-mentioned odometric positioning techniques, and then by turning on the cleaning device 34 in the
25 proximity (the exact position may not be known because of accumulated error) of a boundary line to correct to allow visible detection of the boundary line and thereby its accumulated position error. Such known position can be the same relative position as the position at which the cleaning apparatus 30 started cleaning on the first side of the tennis court 20. In the present embodiment, the

line-cleaning algorithm used on one side of the tennis court **20** is simply repeated on the other side of the tennis court **20**.

[0039] FIG. 9 illustrates a propulsion or drive module **33**, in accordance with an embodiment of the present invention. As shown, the propulsion module **33** includes two drive wheels **36a-36b** and one or two pivoting, rotating or swivel wheels or rollers **37**. Each of the two drive wheels **36a-36b** is driven by one of two differential battery powered drive motors **51a-51b**, respectively. The two-wheel differential steering design exhibits minimal skidding of wheels when turning. Skidding wheels can damage the type of soft surface being traveled over. So, a steering mechanism that minimizes skidding is desirable. The two-wheel differential steering supports turn in place. A feature that is extremely useful for the precise turns required for the purposes of the present invention. With two-wheel differential steering, the steering occurs via the same mechanism as propulsion, avoiding additional steering of specific components. With two-wheel differential steering, there is a separate motor for each drive wheel, obviating the need for the complex drive linkage required when a single engine has to power multiple wheels in an apparatus that requires the two drive wheels to simultaneously have differential rotational rates.

[0040] The propulsion or drive module **33** uses differential steering to move the cleaning apparatus **30** precisely down a boundary line keeping the cleaning device **34** in position for cleaning the boundary line, or simply allowing the cleaning apparatus **30** to move to a specific point on the boundary line. The cleaning apparatus **30** is initially placed in the center over the boundary line and oriented down the boundary line. The propulsion module **33** then drives the cleaning apparatus **20** straight along the boundary line by turning both drive wheels **36a-36b** at the same time. The rotational rate of each of the drive wheels **36a-36b** is dynamically set the amount of drive power delivered to each of the drive wheels **36a-36b**. As the cleaning apparatus **30** is

moving along the boundary line, the line-sensing module **31** continues to capture images that allow a determination of the displacement of the cleaning apparatus **30** from the center of the boundary line. If the cleaning apparatus **30** begins to veer to the left, for example, the propulsion or drive module **33** then
5 applies slightly more differential power to the left drive wheel **36a** than to the right drive wheel **36b**, increasing the rotational rate of the left drive wheel **36a** relative to the rotational rate of the right drive wheel **36b**. Such action causes the path of the cleaning apparatus **30** to curve slightly to the right, thereby correcting its course and keeping the cleaning apparatus **30** precisely on the
10 boundary line being followed. Similar corrective action can be performed on the right drive wheel **36b** if the cleaning apparatus **30** begins to veer to the right.

[0041] As explained previously, the cleaning device **34** can be one of a number of mechanisms for removing debris from a boundary line. The
15 deployment of the cleaning device **34** is under specific program control so that the cleaning device **34** cleans boundary lines as the cleaning apparatus **30** passes over the boundary lines while causing minimal damage of the court areas adjacent to the boundary lines. FIGS. 2-6 illustrate a cleaning device **34** in accordance with an embodiment of the present invention. As shown, the
20 cleaning device **34** includes a cleaning brush **61**, a brush height control wheel **62**, an electric brush motor **63**, a drive train **64**, and a brush assembly hoist mechanism **65**. The cleaning brush **61** is cylindrical in shape with its axis parallel to the court surface. The width (cylindrical length) of the cleaning brush **61** is slightly wider than a boundary line. During operation, the cleaning
25 brush **61** rotates and is in physical contact with a boundary line being cleaned. The brush height control wheel **62** rolls on the boundary line and the rigidity of the brush assembly hoist mechanism **65** maintains the cleaning brush **61** to be in contact with the boundary line. This allows the cleaning brush **61** to clean the boundary line that is not perfectly flat, level and/or smooth. The brush

height control wheel **62** is positioned behind the cleaning brush **61** so as to minimize its interference with the brush operation.

[0042] The brush motor **63** rotates the cleaning brush **61** via the drive train **64**. When the cleaning brush **61** is performing a cleaning function, the
5 brush motor **63** is turned on; otherwise the brush motor **63** is turned off. The drive train **64** is a chain or belt whose linkage transfers the rotation of the brush motor **63** to the rotation of the cleaning brush **61**. The weight of the brush motor **63** is relatively significant; thus, its position can affect the maneuverability and stability of the cleaning apparatus **30**. The arrangements
10 as shown in FIGS. 2-6 allow the physical location of the brush motor **63** to be centered across the width of the cleaning apparatus **30**. The arrangements also allow the brush motor **63** to be positioned behind the cleaning brush **61** and towards the center of the length of cleaning apparatus **30**, enhancing the balance of the cleaning apparatus **30**. In contrast to an arrangement in which
15 the shaft of a brush motor is in line with the brush cylindrical axis, the arrangement as shown allows the brush motor **63** to be positioned away from the court surface to any degree necessary to eliminate any ground clearance issues for the brush motor **63**.

[0043] The brush assembly hoist mechanism **65** is an example of the
20 means for lifting the cleaning brush **61** off the court surface. When the cleaning brush **61** is deployed in its cleaning position, the position of the brush assembly (*i.e.*, the cleaning brush **61**, the brush motor **63** and the brush height control wheel **62**) can move up and down with respect to the drive wheels **36** so that the brush assembly can follow the undulations of the court line (or lack thereof) independently from undulations (or by the lack thereof) being
25 encountered by the drive wheels **36**.

[0044] In an embodiment of the present invention, the microcontroller **47** (see FIG. 7) controls the operation of the line-sensing module **31**, the navigation and control module **32**, the propulsion module **33**, and the cleaning

device 34. A single unified point of control allows the performance of each of the above-mentioned modules to be affected by the state of the rest of the system. For example, the navigation and control module 32 "knows" when the cleaning apparatus 30 is about to reach the end of a boundary line (from
5 knowing its starting point and knowing the distance traveled). When the vicinity of the end of the boundary line, the navigation and control module 32 infers from a camera image containing no court line that the end of the boundary line has been reached. When the navigation and control module 32 knows the cleaning apparatus 30 to be only part of the way down a boundary
10 line, as opposed to being at the end of a boundary line, and the line-sensing module 31 reports that the current camera image contains no boundary line, then what is inferred is that the cleaning apparatus 30 has failed to follow the boundary line or that the boundary line has become obscured from view, for example. Similarly, when the navigation and control module 32 "knows" that
15 the cleaning apparatus 30 is approaching the end of the boundary line where it will have to stop and turn, then that information causes the control of the propulsion module 33 to decelerate the cleaning apparatus 30 appropriately such that a precise turn can be made. Also, when the navigation and control module 31 "knows" the cleaning apparatus 30 is at the end of a boundary line
20 (because of positioning information and the interpretation of the image provided by the line-sensing module 31), then the drive motor 63 for the cleaning brush 61 is turned off and the cleaning device 34 is raised to a position at which the cleaning device 34 does not in contact with the court surface.

[0045] The tennis court 20 can be divided into two half courts, one on
25 each side of the net. The algorithm for cleaning boundary lines involves working the first side of the tennis court 20 and then crosses the net to the second side of the tennis court 20 and essentially repeating the same work that was done in the first side of the tennis court 20 (see, e.g., FIGS. 11-13). For the cleaning apparatus 30 to clean a first half of the tennis court 20, the

cleaning apparatus 30 is manually positioned on the single's sideline 21a at the net heading towards the baseline 23a as shown in FIG. 1. The rest of the operations is performed automatically by the cleaning apparatus 30. The apparatus 30, for example, can clean along the single's sideline 21a from the net towards the baseline 23a and stop at the intersection of the sideline 21a and the baseline 23a. The apparatus rotates right 90 degrees to head towards the double's sideline 22a, and cleans along the baseline 22a and stops at the double's sideline 22a. The apparatus 30 then rotates right 90 degrees to head towards the net. It cleans the double's sideline 22a and stops at the net. The apparatus 30 then rotates 180 degrees towards the baseline 23a, follows the double's sideline 22a from the net and stops at the baseline 23a. The apparatus again rotates left 90 degrees to head towards the single's sideline 21b, cleans the baseline 23a from the double's sideline 22a and stops at the center mark of baseline 23a; The apparatus rotates left 90 degrees to head towards the net, cleans the center mark from the baseline 23a to the end of the line, backs up to the intersection of the center mark and the baseline 23a, and rotates right 90 degrees to head towards the double's sideline 22b. The apparatus 30 cleans the baseline 23a from the center mark to the double's sideline 22b and stops at the sideline 22b. The apparatus rotates 180 degrees to head across the baseline 23a, follows the baseline 23a from the double's sideline 22b to the single's sideline 21b, and stops at the single's sideline 21b. The apparatus 30 once again rotates 90 degrees to the right to head along the single's sideline 21b, cleans the single's sideline 21b from the baseline 23a to the service line 24a, and stops at the service line 24a. The apparatus then rotates 90 degrees to the left to head along the service line 24a.

[0046] The apparatus 30 cleans the service line 24a from the single's sideline 21b to the single's sideline 21a and stops at the single's sideline 21a. It rotates 90 degrees to the right to head along the single's sideline 21a toward the net, cleans the single's sideline 21a from the service line to the net and stops,

rotates 180 degrees to head away from the net towards the baseline, and follows the single's sideline **21a** to the service line and stops. The apparatus **30** then rotates 90 degrees to the left to head across the service line, follows the service line to the center line and stops, rotates 90 degrees to the left to head
5 toward the net, and cleans the center line from the service line to the net and stops. It then rotates 180 degrees to head away from the net toward the service line, follows the center line to the service line and stops, rotates 90 degrees to the left to head along the service line to the single's sideline **21b**, and follows the service line to the single's sideline **21b** and stops. The apparatus **30** once
10 again rotates 90 degrees to the left to head along the single's sideline **21b** toward the net, cleans the single's sideline **21b** from the service line to the net and stops, rotates 180 degrees to head away from the net toward the baseline **23a**, and follows the single's sideline **21b** from the net to the baseline **23a** and stops.

15 **[0047]** The apparatus **30** rotates 90 degrees to the left to head across the baseline **23a** towards the double's sideline **22b**, follows the baseline to the double's sideline **22b** and stops, rotates 90 degrees to the left to head along the double's sideline **22b** toward the net, cleans the double's sideline **22b** from the baseline **23a** to the net and stops. The lines on the first half court are done.

20 **[0048]** The apparatus now rotates 90 degrees to the right to head parallel to the net outside the court boundaries, moves straight ahead a distance that is just past the net post and stops, rotates 90 degrees to the left to head in a direction parallel to the court sidelines, moves straight a distance that is just past the net post and stops. The apparatus position is now on the second half
25 court. The apparatus **30** rotates 90 degrees to the left to head parallel to the net toward the center of the court, moves straight to the second half court left singles sideline and stops at the left singles sideline. The apparatus **30** rotates 90 degrees to the right to head along the single's sideline **21a** towards the baseline.

[0049] For example, there are at least two methods for moving the cleaning apparatus 30 from one side of the net to the other. FIG. 11 depicts points P1, P2, P3 and P4 on the tennis court 20 at which the cleaning apparatus 30 makes a turn to move around a net post. The points P1-P4 are defined for illustration purpose only and have no physical manifestation on the tennis court 20. Point P1 is the end position of the cleaning apparatus 30 after cleaning a first side of the tennis court 20. The cleaning apparatus 30 then moves to the second side of the tennis court 20, as follows.

[0050] The apparatus 30 rotates to head towards point P2, moves from point P1 to point P2, rotates to head towards point P3, and moves from point P2 to point P3. The apparatus then rotates to head towards point P4, moves from P3 to point P4, and rotates to head away from the net and towards the baseline 23b.

[0051] As the cleaning apparatus 30 approaches point P4, the cleaning apparatus 30 can enable the cleaning brush 34 to expose the single's sideline 21b at point P4 and therefore be able to visually identify when its path intersects the single's sideline 21b. For all of the other parts of the maneuver, the cleaning brush 34 can be turned off. Except for the visual determination of when point P4 is reached, all the movement and navigation for this maneuver around the net can be controlled by odometric techniques.

[0052] Another method requires a modification to the tennis court 20 by adding three tracking guidelines 91-93 around a net post outside the boundary lines of the tennis court 20 as shown in FIG. 11. The tracking guidelines 91-93 are made of the same material as the boundary lines and are held in place in the same manner as the boundary lines. The purpose of the tracking guidelines 91-93 is to serve as a guideline for the cleaning apparatus 30 to follow from one side of the net to the other. The tracking guidelines 91-93 are at defined positions and are of defined length. The steps for the cleaning apparatus 30 to go around the net in this other method are the same as in the first method

described, except that tracking guidelines **91-93** are used to guide the cleaning apparatus **30** along. As the cleaning apparatus **30** is traveling from P3 and approaches the double's sideline **22b**, the cleaning brush **61** is turned off and the guideline tracking mechanism is disabled, and odometric techniques are
5 used to navigate the cleaning apparatus **30** through the rest of the way to point P4.

[0053] With the first method described, precision errors accumulate from point P1 all the way to point P4 so that the total precision error when point P4 is reached may be considerable large, which can limit the ability of the cleaning
10 apparatus **30** to locate point P4. With the second method described, there is no accumulation of precision error so the position error at point P4 is only a precision error that is incurred in moving from just before the double's sideline **22b** to point P4, which should be a relatively insignificant amount of error. The second method described requires some modification to the tennis court
15 **20**, albeit outside the boundaries of play, but the first method described works on any regulation tennis court without any modification at all.

[0054] Figure 10 is a flowchart illustrating a method for cleaning boundary lines on a playing surface of a tennis court, in accordance with an embodiment of the present invention. Starting at block **100**, a user places the
20 cleaning apparatus **30** facing away from the net on the single's sideline 21a of the tennis court **20** to be cleaned, as shown in block 101. The cleaning apparatus **20** follows a preprogrammed path on the boundary lines on the first half of the tennis court **20**, as depicted in block **102**. The cleaning apparatus **30** completes preprogrammed path for one side of the court, as shown in block
25 **103**. The cleaning apparatus **30** then follows a preprogrammed path from the double's sideline **22b** around the net post to single's sideline on the opposite side of the net, as depicted in block **104**. The cleaning apparatus **30** follows a preprogrammed path on the boundary lines on the second half of the tennis

court 20, verifying path with the on-board line-sensing module, as shown in block 105.

[0055] Figure 10 is a flowchart illustrating the operations of the cleaning apparatus 30 for cleaning boundary lines on a playing surface of a tennis court, in accordance with an embodiment of the present invention. Starting with block 110, an array of emitters illuminates the court area on which an optical sensing device is trained, as shown in block 111. The lens focuses image on the sensor and the sensor sends information to a microcontroller, as shown in block 112. A determination is made as to whether or not a line is visible, as shown in block 113. If the line is visible, the microcontroller compares information received from sensor with the desired line position, as depicted in block 114. Another determination is made as to whether or not the line is in a correct position, as shown in block 115. If the line is not in the correct position, the position of the cleaning apparatus is adjusted relative to the line, as depicted in block 116. Otherwise, if the line is in the correct position, the microcontroller compares the information received from the sensor with the preprogrammed information, as shown in block 117.

[0056] Next, a determination is made as to whether or not the cleaning apparatus is in the correct position, as shown in block 118. If the cleaning apparatus is not in the correct position, the position of the cleaning apparatus is adjusted relative to the preprogrammed information, as depicted in block 119. Another determination is made as to whether or not the preprogrammed cleaning circuit has been completed, as shown in block 120. If the preprogrammed cleaning circuit has not been completed, the process returns to block 121; otherwise, the process exits at block 121.

[0057] As illustrated in FIGS. 1-13, and as described above, the present invention also includes various methods of cleaning at least one line of a surface. A method for cleaning boundary lines on a game playing surface, for example, includes directing a cleaning device to move along boundary lines on

a game playing surface responsive to a set of programmed directions and cleaning the boundary lines when the cleaning device is moving along the boundary lines. The method can also include the directing step having a step of determining a current position of the cleaning device by using a known initial
5 position and an orientation of the cleaning device on the game playing surface and can use wheel dimensions and rotation data and a predetermined length of each boundary line. The game playing surface can advantageously be a surface of a tennis court, and more advantageously a clay surface of a tennis court, and the method can further include adding a plurality of tracking guidelines situated
10 around a net post of the game playing surface for guiding the cleaning device to move around the net post. The method can still further include sensing a location of a boundary line of a tennis court.

[0058] Another method for cleaning boundary lines on a game playing surface can include directing a cleaning device to move along boundary lines
15 on a game playing surface responsive to a set of programmed directions and selectively positioning a cleaning tool on a boundary line to clean the boundary line as the cleaning device is moving over the boundary line. The method can also include the directing step having a step of determining a current position of the cleaning device by using a known initial position and an orientation of
20 the cleaning device on the game playing surface. The method can also include determining step further using wheel dimensions and rotation data and a predetermined length of each boundary line. The game playing surface preferably is a surface of a tennis court, and the method further can include adding a plurality of tracking guidelines situated around a net post of the game
25 playing surface for guiding the cleaning device to move around the net post. The method can also include sensing a location of a boundary line of a tennis court.

[0059] Yet another method for cleaning boundary lines on a game playing surface, which includes a first playing surface and a second playing

surface separated from each other by a net connected between a plurality of posts, can include directing a cleaning device to move along boundary lines on the first playing surface responsive to a set of programmed directions, cleaning the boundary lines on the first playing surface as the cleaning device is moving
5 over the boundary lines on the first playing surface, directing the cleaning device to move around one of the net post to position the cleaning device on the second playing surface, and cleaning the boundary lines on the first playing surface as the cleaning device is moving over the boundary lines on the second playing surface. The directing step can include a step of determining a current
10 position of the cleaning device by using a known initial position and an orientation of the cleaning device on the game playing surface. The determining step can further use wheel dimensions and rotation data and a predetermined length of each boundary line. The game playing surface is preferably a surface of a tennis court, and the method can further include
15 adding a plurality of tracking guidelines situated around a net post of the game playing surface for guiding the cleaning device to move around the net post. The method can further include sensing a location of or presence of a boundary line of the game playing surface.

[0060] The present invention, as described and illustrated, also includes
20 software or a computer program products residing on a computer usable medium for directing a cleaning device to clean at least one line on a surface. As described herein and understood by those skilled in the art, the code means is preferably software or computer program code or language as understood by those skilled in the art. A computer program product program code means for
25 directing a cleaning device to move along at least one line of a surface and program code means for cleaning the at least one line on the surface when the cleaning device is moving along the at least one line. The program code means for directing can further include program code means for determining a current position of the cleaning device by using a known initial position and an

orientation of the cleaning device on the surface. The program code means for determining further uses wheel dimensions and rotation data and a predetermined length of each line. The surface can advantageously be a surface of a tennis court.

- 5 **[0061]** Another computer program product for cleaning boundary lines on a game playing surface according to the present invention can include program code means for directing a cleaning device to move along boundary lines on a game playing surface responsive to a set of programmed directions and program code means for selectively positioning a cleaning tool on a
- 10 boundary line to clean the boundary line as the cleaning device is moving over the boundary line. The program code means for directing step can further include program code means for determining a current position of the cleaning device by using a known initial position and an orientation of the cleaning device on the game playing surface. The program code means for determining
- 15 can further use wheel dimensions and rotation data and a predetermined length of each boundary line. The game playing surface can advantageously be a surface of a tennis court.

- [0062]** Still another computer program product for cleaning boundary lines on a game playing surface, which the game playing surface includes a
- 20 first playing surface and a second playing surface separated from each other by a net connected between net posts, can include program code means for directing a cleaning device to move along boundary lines on the first playing surface responsive to a set of programmed directions, program code means for cleaning the boundary lines on the first playing surface as the cleaning device
- 25 is moving over the boundary lines on the first playing surface, program code means for directing the cleaning device to move around one of the net post to position the cleaning device on the second playing surface, and program code means for cleaning the boundary lines on the first playing surface as the cleaning device is moving over the boundary lines on the second playing

surface. The program code means for directing can further include program code means for determining a current position of the cleaning device by using a known initial position and an orientation of the cleaning device on the game playing surface. The program code means for determining also can further use
5 wheel dimensions and rotation data and a predetermined length of each boundary line as understood by those skilled in the art. The game playing surface advantageously can be a surface of a tennis court as illustrated and described.

[0063] As has been described, the present invention provides an
10 apparatus for cleaning boundary lines on a playing surface of a tennis court. It is also important to note that although the present invention has been described in the context of a fully functional computer system, those skilled in the art will appreciate that the mechanisms of the present invention are capable of being distributed as a program product in a variety of forms, and that the present
15 invention applies equally regardless of the particular type of signal bearing media utilized to actually carry out the distribution. Examples of signal bearing media include, without limitation, recordable type media such as floppy disks, CD ROMs, various programmable and re-writable ROMs, and transmission type media such as analog or digital communications links.

20 **[0064]** Although the invention has been particularly shown and described with reference illustrated preferred embodiments, it will be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention.

25

THAT CLAIMED IS:

1. An apparatus for cleaning lines on a game playing surface, the apparatus comprising:

- 5 a chassis;
sensing means connected to the chassis for sensing a location of a line associated with a game playing surface that needs to be cleaned;
driving means connected to the chassis for driving the chassis in a selected direction of travel;
10 controlling means connected to the chassis, in communication with the driving means, and responsive to the sensing means for controlling the driving means to thereby direct the chassis to be driven along the line that needs to be cleaned in the selected direction of travel;
and
15 a cleaning device connected to the chassis to clean the line when the chassis is being driven along the line.

2. An apparatus as defined in Claim 1, wherein the sensing means includes a sensing device positioned at an elevation higher than the game playing surface and oriented to capture an image in a direction transverse to the
20 game playing surface.

3. An apparatus as defined in Claim 2, wherein the sensing device comprises an optical sensing device, wherein the optical sensing device includes at least one sensor and at least one lens, and wherein the at least one sensor includes a plurality of photodiodes positioned to capture an image
25 received through the lens.

4. An apparatus as defined in Claim 3, wherein the optical sensing device further includes a sensor interface positioned to serially shift out the captured image defined as a plurality of pixels, and wherein a brightness level

of each pixel is represented by at least one voltage signal received over a controlled period of time.

5 5. An apparatus as defined in Claim 4, wherein the controlling means includes a line determiner positioned to determine whether a boundary line is present based on the captured image.

6. An apparatus as defined in Claim 5, wherein the controlling means further includes a position analyzer responsive to the line determiner to analyze the captured image received from the sensor interface so that a lateral position of the chassis is provided to the driving means and so that a focus of view of the sensing means is oriented on the line.

7. An apparatus as defined in Claim 2, wherein the sensing means includes an array of illuminators positioned to illuminate the game playing surface for the optical sensing device.

8. An apparatus as defined in Claim 1, wherein the sensing means is positioned on the chassis downstream from the cleaning device as the cleaning device is being driven along the direction of travel.

9. An apparatus as defined in Claim 1, wherein the driving means comprises at least two drive wheels and a differential drive connected to each of the at least two drive wheels and positioned to independently drive each of the at least two drive wheels so that a position of the chassis when being driven along the line is compensated to enhance orientation of the chassis along the line.

10. An apparatus as defined in Claim 1, wherein the cleaning device includes a frame connected to the chassis, a cleaning tool connected to the frame, and a height control wheel connect to the frame to control the positional distance of the cleaning tool from the game playing surface.

11. An apparatus as defined in Claim 10, wherein the cleaning device further includes a tool drive motor connected to the frame and responsive to the controlling means to selectively drive the cleaning tool, and wherein the cleaning device further includes a tool lift assembly connected to the frame and
5 to the cleaning tool to selectively raise the cleaning tool from and lower the cleaning tool to the game playing surface.

12. An apparatus as defined in Claim 1, wherein the controlling means includes a memory having at least one of the following predetermined parameters stored therein: a set of predetermined line parameters, a set of drive
10 parameters, and a set of game playing surface parameters, wherein the controlling means reduces a drive speed of the driving means to slow down the chassis responsive to the set of predetermined parameters when the chassis approaches an end of the line being cleaned, and wherein the game playing surface comprises a surface of a tennis court.

13. An apparatus as defined in Claim 12, wherein the predetermined parameters further include a known initial position of the chassis and operational parameters of the cleaning device, wherein the set of predetermined drive parameters includes wheel dimension and rotation data, and wherein the set of predetermined line parameters includes a predetermined length of each
15 boundary line of the tennis court.

14. A cleaning apparatus for cleaning boundary lines on a game playing surface, the cleaning apparatus comprising:

- a cleaning device;
- a drive positioned to drive the cleaning device along at least one
25 boundary line of a game playing surface; and
- a controller in communication with the drive and the cleaning device to selectively control the driving of the cleaning device to clean the at least one boundary line on the game playing surface when the drive is driving the cleaning device along the at least one boundary line.

15. A cleaning apparatus as defined in Claim 14, wherein the controller includes means for directing the cleaning device to move along boundary lines on the game playing surface responsive to a set of programmed directions.

5 16. A cleaning apparatus as defined in Claim 14, wherein the controller includes a memory having a set of programmed directions stored therein, and wherein the drive is responsive to the set of programmed directions.

10 17. A cleaning apparatus as defined in Claim 14, further comprising a sensing device positioned to sense a location of the boundary lines associated with the game playing surface that need to be cleaned.

15 18. A cleaning apparatus as defined in Claim 17, wherein the sensing device is positioned at an elevation higher than the game playing surface and oriented to capture an image in a direction transverse to the game playing surface.

20 19. A cleaning apparatus as defined in Claim 18, wherein the sensing device comprises an optical sensing device, wherein the optical sensing device has at least one sensor and at least one lens, and wherein the at least one sensor includes a plurality of photodiodes positioned to capture an image received through the lens.

25 20. A cleaning apparatus as defined in Claim 19, wherein the optical sensing device further includes a sensor interface positioned to serially shift out the captured image defined as a plurality of pixels, and wherein a brightness level of each pixel is represented by at least one voltage signal received over a controlled period of time.

21. A cleaning apparatus as defined in Claim 18, wherein the controller includes a line determiner positioned to determine whether a boundary line is present based on the captured image.

22. A cleaning apparatus as defined in Claim 21, wherein the controller further includes a position analyzer responsive to the line determiner to analyze the captured image received from the sensor interface so that a lateral position of the cleaning device is provided to the drive and so that a
5 focus of view of the sensing device is oriented on the line.

23. A cleaning apparatus as defined in Claim 18, wherein the sensing device includes an array of illuminators positioned to illuminate the game playing surface for the sensing device.

24. A cleaning apparatus as defined in Claim 18, wherein the sensing
10 device is positioned downstream from the cleaning device as the cleaning device is being driven along the direction of travel.

25. A cleaning apparatus as defined in Claim 14, wherein the drive comprises at least two drive wheels and a differential drive connected to each of the at least two drive wheels and positioned to independently drive each of
15 the at least two drive wheels so that a position of the position of the cleaning device when being driven along the line is compensated to enhance orientation of the cleaning device along the line.

26. A cleaning apparatus as defined in Claim 14, wherein the cleaning device includes a frame, a cleaning tool connected to the frame, and a
20 height control wheel connect to the frame to control the positional distance of the cleaning tool from the game playing surface.

27. A cleaning apparatus as defined in Claim 26, wherein the cleaning device further includes a tool drive motor connected to the frame and responsive to the controller to selectively drive the cleaning tool, and wherein
25 the cleaning device further includes a tool lift assembly connected to the frame and to the cleaning tool to selectively raise the cleaning tool from and lower the cleaning tool to the game playing surface.

28. A cleaning apparatus as defined in Claim 14, wherein the controller includes a memory having at least one of the following predetermined parameters stored therein: a set of predetermined line parameters, a set of drive parameters, and a set of game playing surface parameters, wherein the controller reduces a drive speed of the driving means to slow down the chassis responsive to the set of predetermined parameters when the chassis approaches an end of the line being cleaned, and wherein the game playing surface comprises a surface of a tennis court.

29. A cleaning apparatus as defined in Claim 28, wherein the predetermined parameters further include a known initial position of the cleaning device and operational parameters of the cleaning device, wherein the set of predetermined drive parameters includes wheel dimension and rotation data, and wherein the set of predetermined line parameters includes a predetermined length of each boundary line of the tennis court.

30. A method for cleaning boundary lines on a game playing surface, the method comprising:

directing a cleaning device to move along boundary lines on a game playing surface responsive to a set of programmed directions; and cleaning the boundary lines when the cleaning device is moving along the boundary lines.

31. A method as defined in Claim 30, wherein the directing step further includes a step of determining a current position of the cleaning device by using a known initial position and an orientation of the cleaning device on the game playing surface.

32. A method as defined in Claim 31, wherein the determining step further uses wheel dimensions and rotation data and a predetermined length of each boundary line.

33. A method as defined in Claim 30, wherein the game playing surface comprises a surface of a tennis court, and the method further comprises adding a plurality of tracking guidelines situated around a net post of the game playing surface for guiding the cleaning device to move around the net post.

5 34. A method as defined in Claim 30, further comprising sensing a location of a boundary line of a tennis court.

35. A method for cleaning boundary lines on a game playing surface, the method comprising:

10 directing a cleaning device to move along boundary lines on a game playing surface responsive to a set of programmed directions; and
 selectively positioning a cleaning tool on a boundary line to clean the boundary line as the cleaning device is moving over the boundary line.

15 36. A method as defined in Claim 35, wherein the directing step further includes a step of determining a current position of the cleaning device by using a known initial position and an orientation of the cleaning device on the game playing surface.

20 37. A method as defined in Claim 36, wherein the determining step further uses wheel dimensions and rotation data and a predetermined length of each boundary line.

38. A method as defined in Claim 35, wherein the game playing surface comprises a surface of a tennis court, and the method further comprises adding a plurality of tracking guidelines situated around a net post of the game playing surface for guiding the cleaning device to move around the net post.

25 39. A method as defined in Claim 35, further comprising sensing a location of a boundary line of a tennis court.

40. A method for cleaning boundary lines on a game playing surface, wherein the game playing surface includes a first playing surface and a second playing surface separated from each other by a net connected between a plurality of posts, the method comprising:

5 directing a cleaning device to move along boundary lines on the first playing surface responsive to a set of programmed directions;

cleaning the boundary lines on the first playing surface as the cleaning device is moving over the boundary lines on the first playing surface;

10 directing the cleaning device to move around one of the net post to position the cleaning device on the second playing surface; and

cleaning the boundary lines on the first playing surface as the cleaning device is moving over the boundary lines on the second playing surface.

15 41. A method as defined in Claim 40, wherein the directing step further includes a step of determining a current position of the cleaning device by using a known initial position and an orientation of the cleaning device on the game playing surface.

20 42. A method as defined in Claim 41, wherein the determining step further uses wheel dimensions and rotation data and a predetermined length of each boundary line.

25 43. A method as defined in Claim 40, wherein the game playing surface comprises a surface of a tennis court, and the method further comprises adding a plurality of tracking guidelines situated around a net post of the game playing surface for guiding the cleaning device to move around the net post.

44. A method as defined in Claim 40, further comprising sensing a location of a boundary line of the game playing surface.

45. A computer program product residing on a computer usable medium for directing a cleaning device to clean at least one line on a surface, the computer program product comprising:

5 program code means for directing a cleaning device to move along at least one line of a surface; and

 program code means for cleaning the at least one line on the surface when the cleaning device is moving along the at least one line.

46. A computer program product as defined in Claim 45, wherein the program code means for directing further includes program code means for
10 determining a current position of the cleaning device by using a known initial position and an orientation of the cleaning device on the surface.

47. A computer program product as defined in Claim 46, wherein the program code means for determining further uses wheel dimensions and rotation data and a predetermined length of each line.

15 48. A computer program product as defined in Claim 45, wherein the surface comprises a surface of a tennis court.

49. A computer program product for cleaning boundary lines on a game playing surface, the computer program product comprising:

20 program code means for directing a cleaning device to move along boundary lines on a game playing surface responsive to a set of programmed directions; and

 program code means for selectively positioning a cleaning tool on a boundary line to clean the boundary line as the cleaning device is moving over the boundary line.

25 50. A computer program product as defined in Claim 49, wherein the program code means for directing step further includes program code means for determining a current position of the cleaning device by using a known

initial position and an orientation of the cleaning device on the game playing surface.

51. A computer program product as defined in Claim 50, wherein the program code means for determining further uses wheel dimensions and rotation data and a predetermined length of each boundary line.

52. A computer program product as defined in Claim 49, wherein the game playing surface comprises a surface of a tennis court.

53. A computer program product for cleaning boundary lines on a game playing surface, wherein the game playing surface includes a first playing surface and a second playing surface separated from each other by a net connected between net posts, the computer program product comprising:

program code means for directing a cleaning device to move along boundary lines on the first playing surface responsive to a set of programmed directions;

15 program code means for cleaning the boundary lines on the first playing surface as the cleaning device is moving over the boundary lines on the first playing surface;

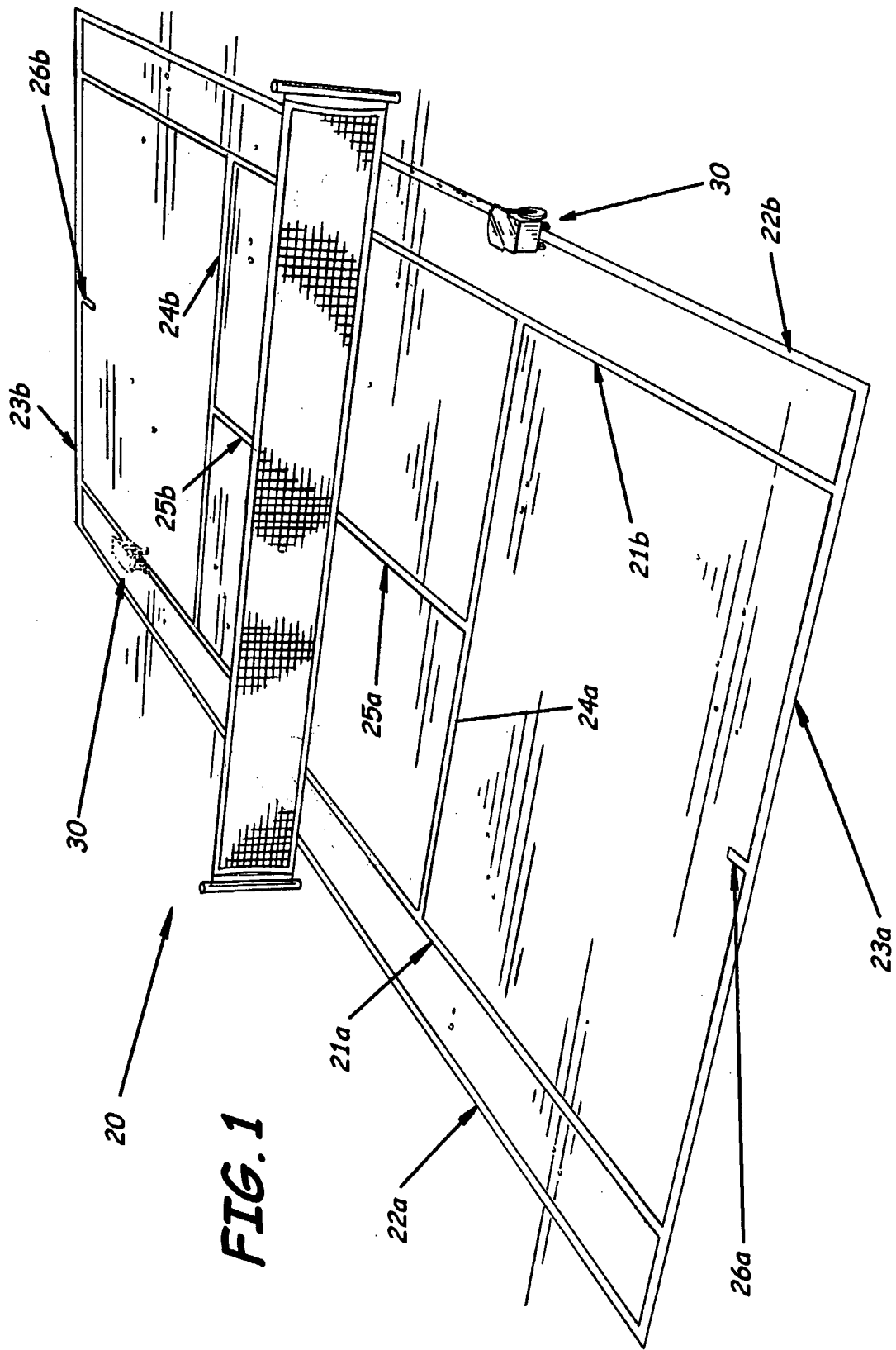
program code means for directing the cleaning device to move around one of the net post to position the cleaning device on the second playing surface; and

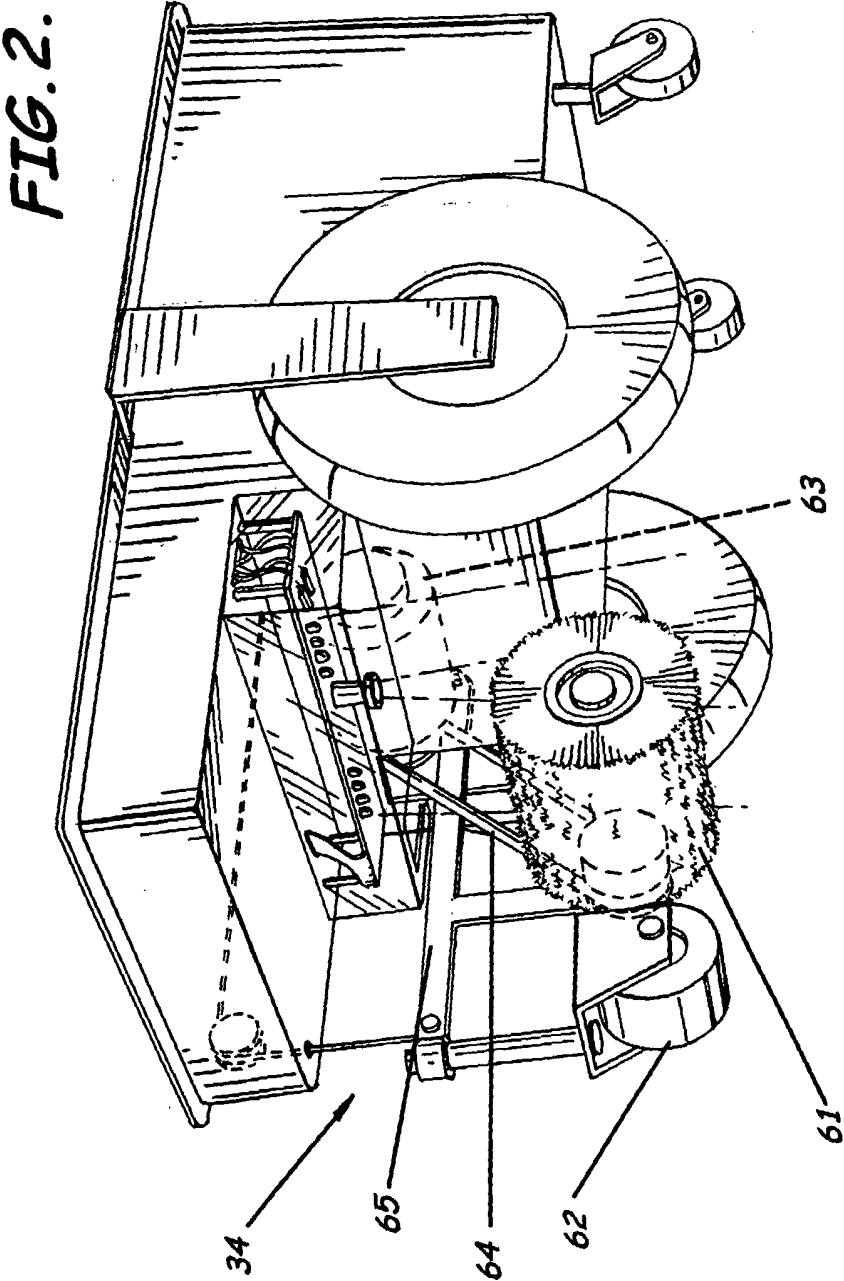
20 program code means for cleaning the boundary lines on the first playing surface as the cleaning device is moving over the boundary lines on the second playing surface.

54. A computer program product as defined in Claim 53, wherein the program code means for directing further includes program code means for determining a current position of the cleaning device by using a known initial position and an orientation of the cleaning device on the game playing surface.

55. A computer program product as defined in Claim 54, wherein the program code means for determining further uses wheel dimensions and rotation data and a predetermined length of each boundary line.

56. A computer program product as defined in Claim 53, wherein the
5 game playing surface comprises a surface of a tennis court.





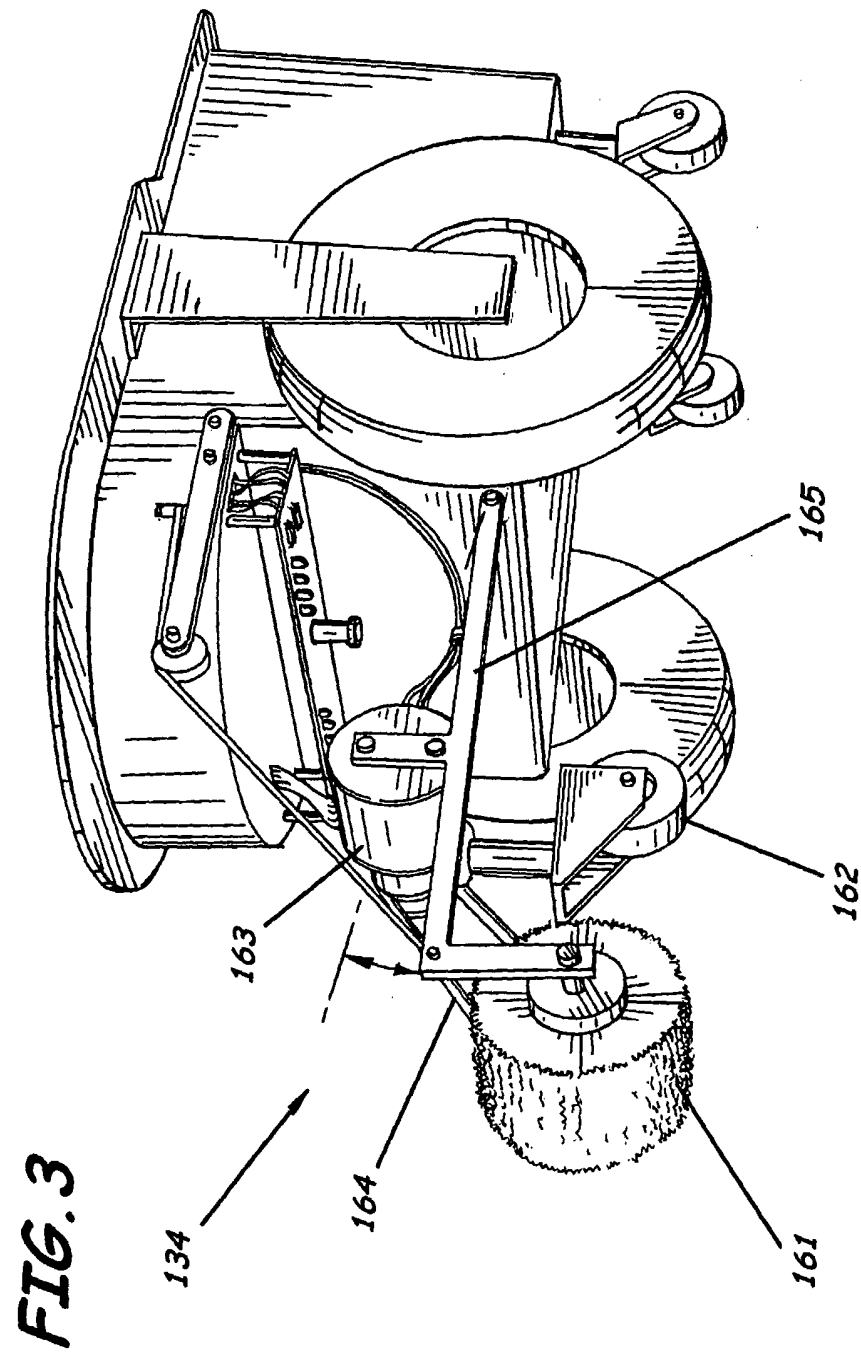
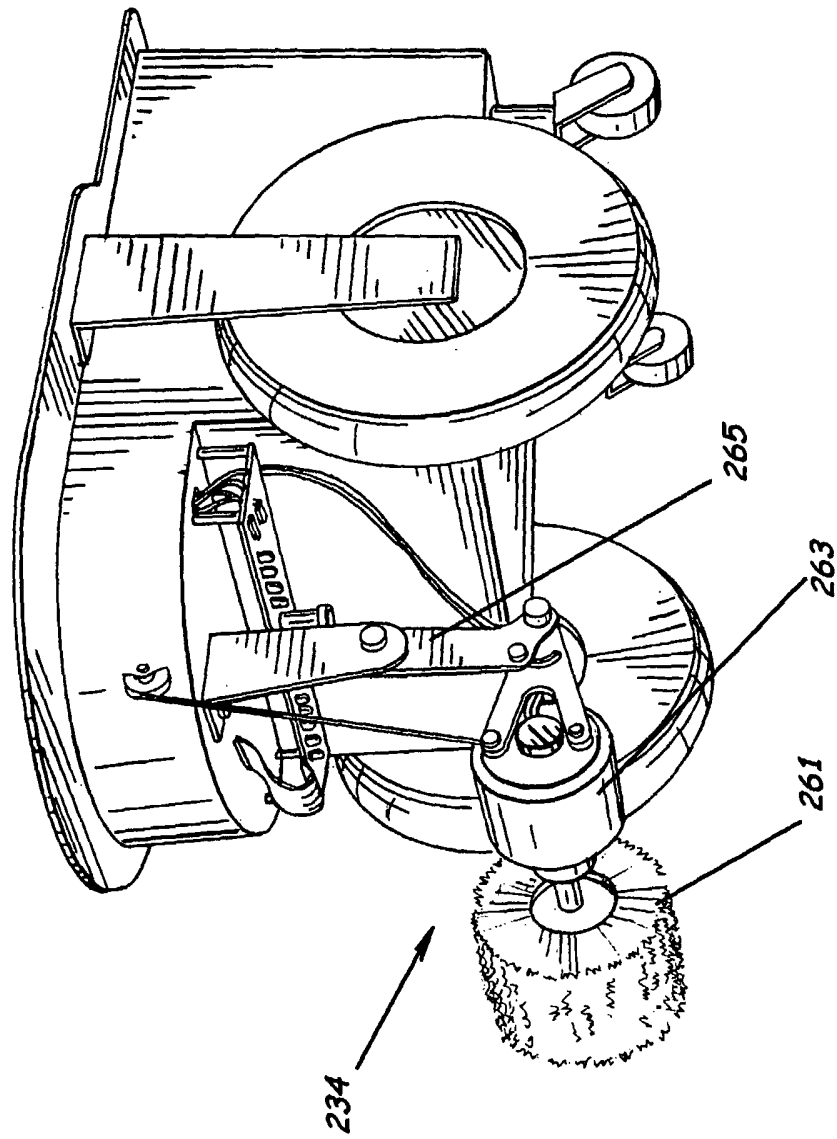
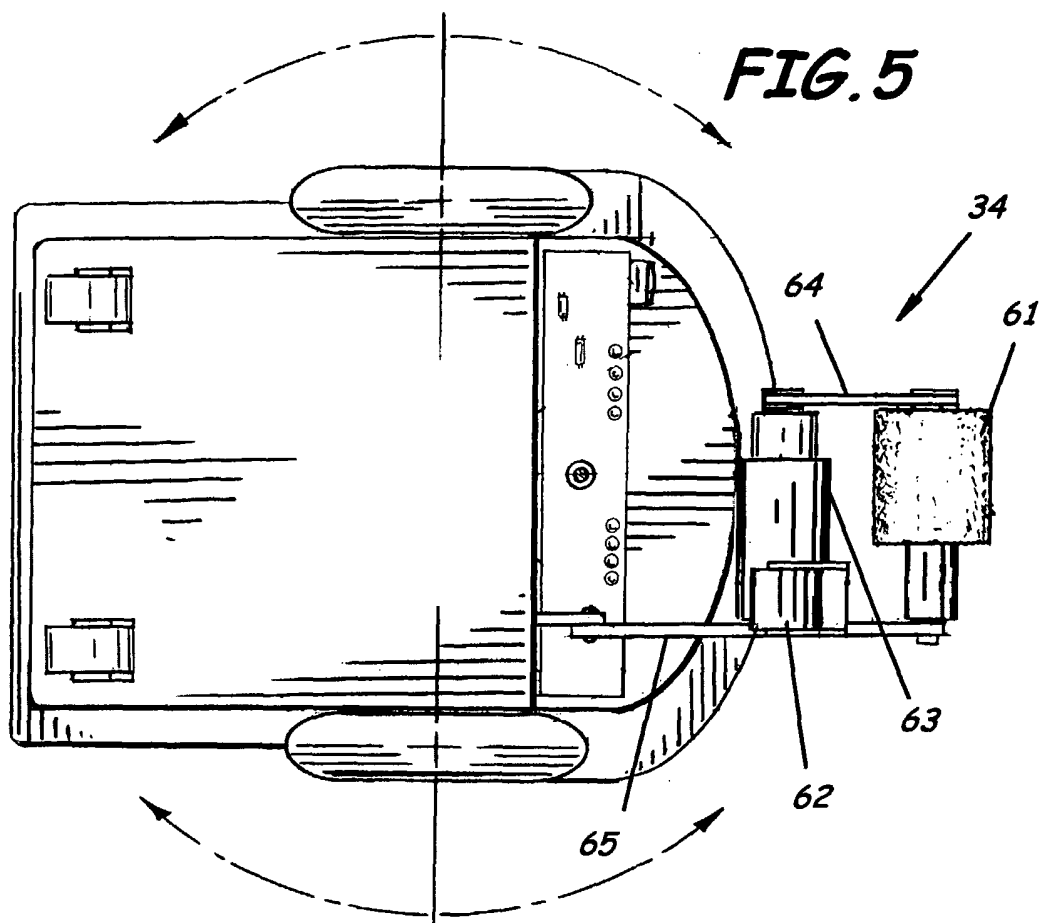
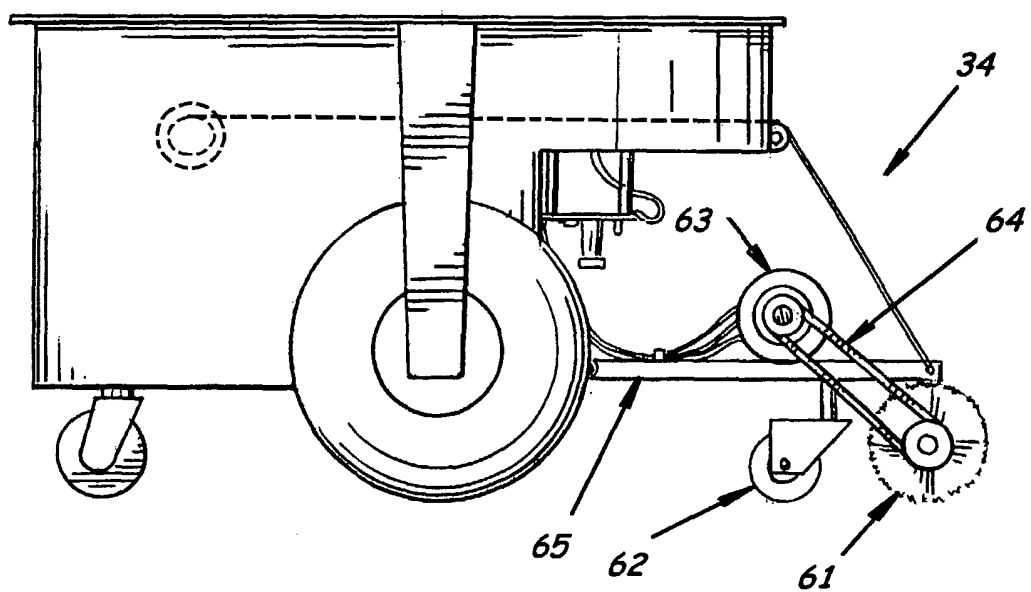
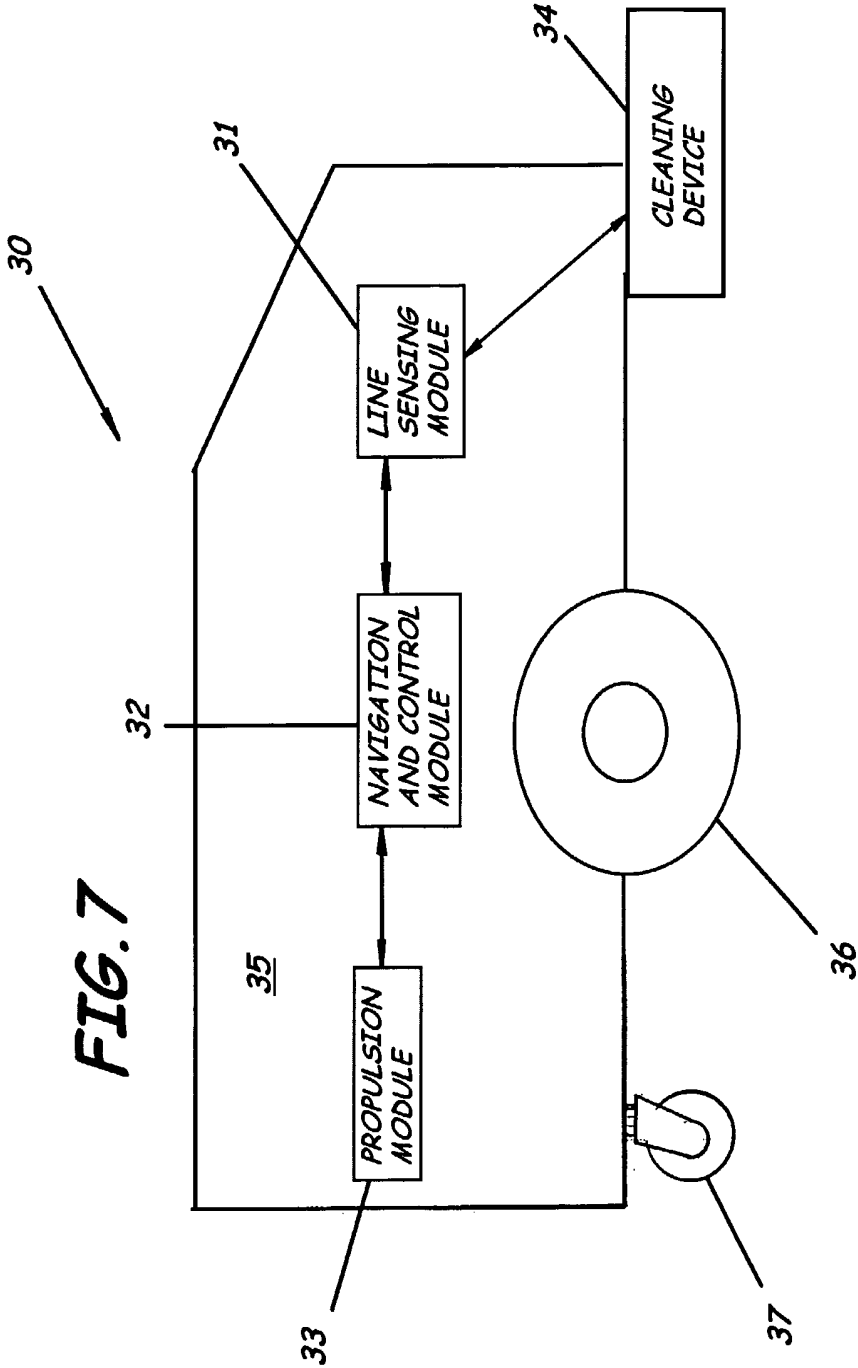


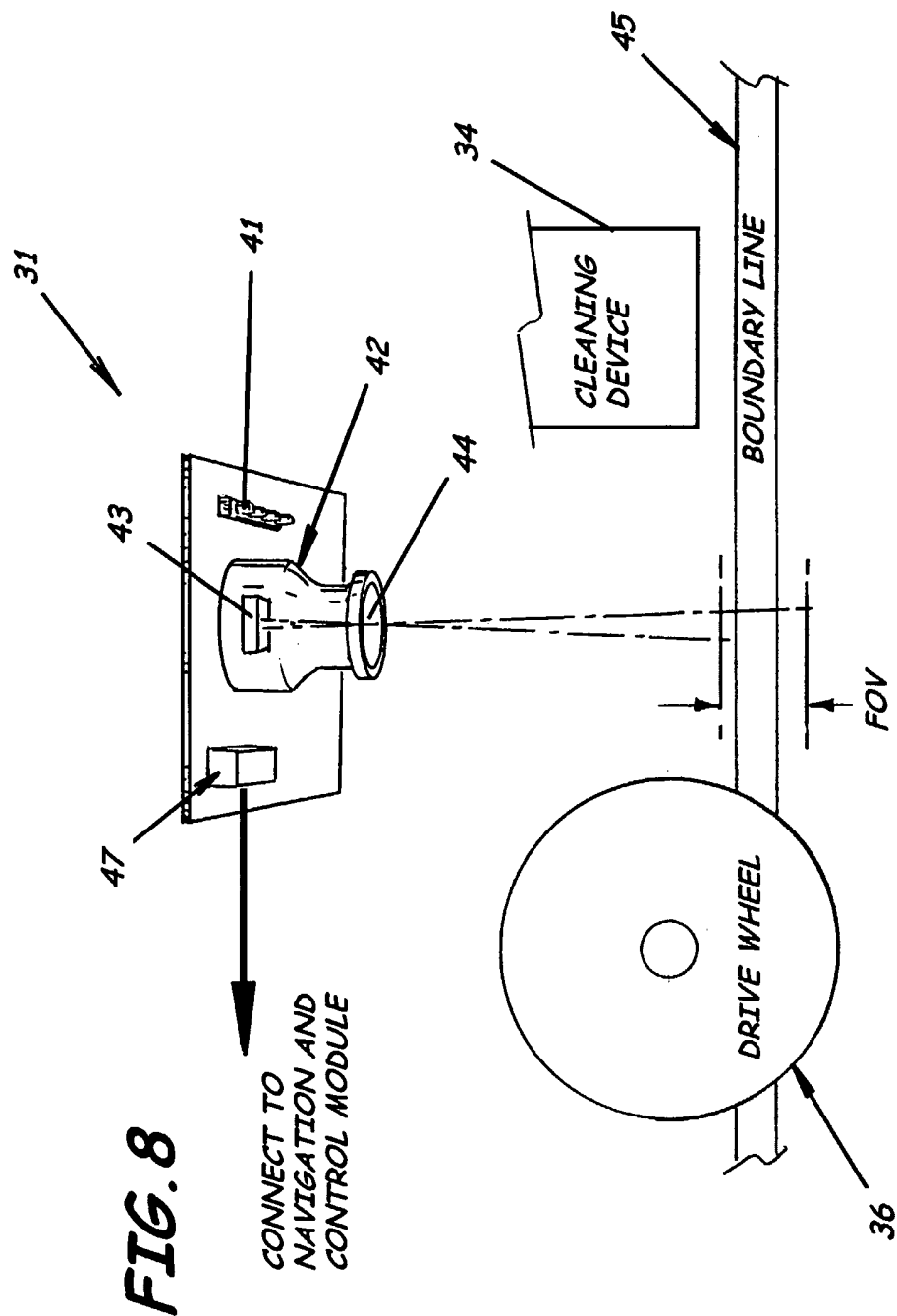
FIG. 4



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**FIG. 6**





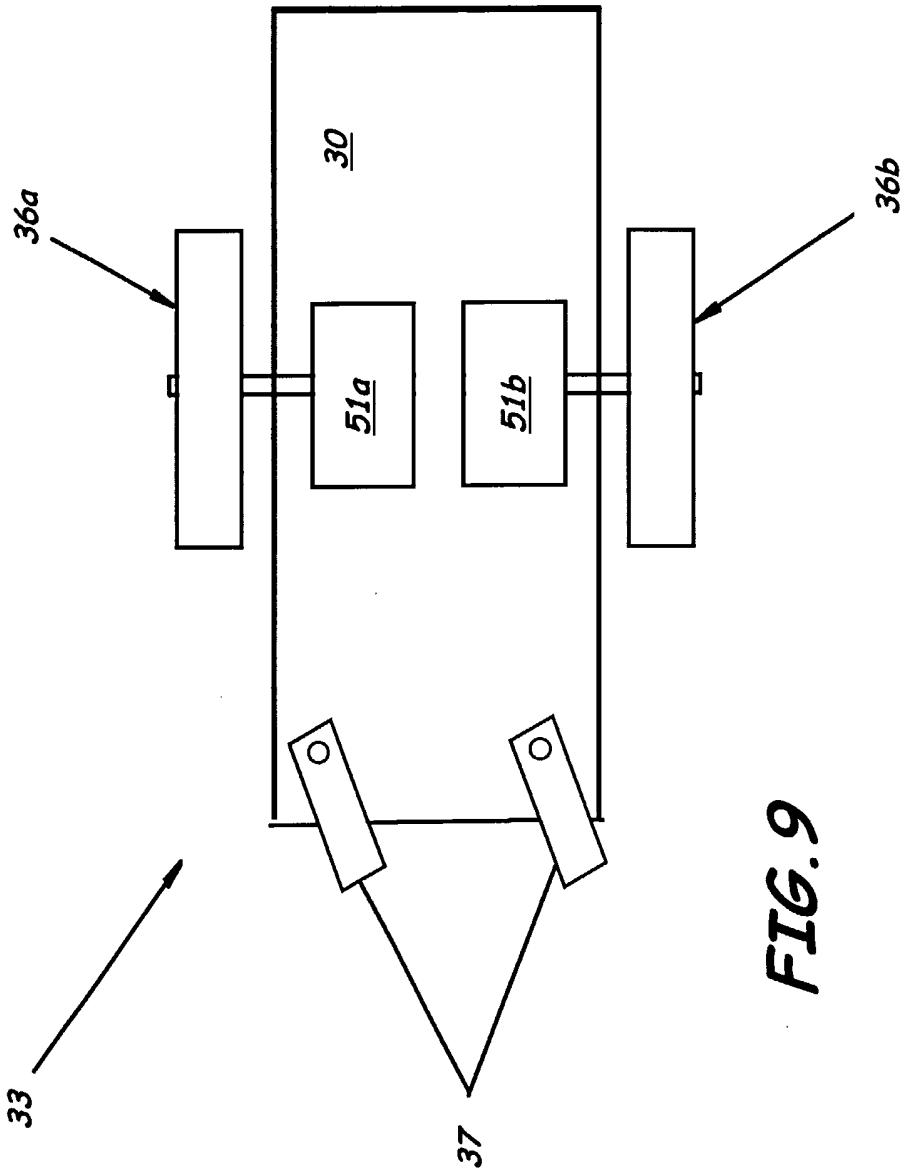
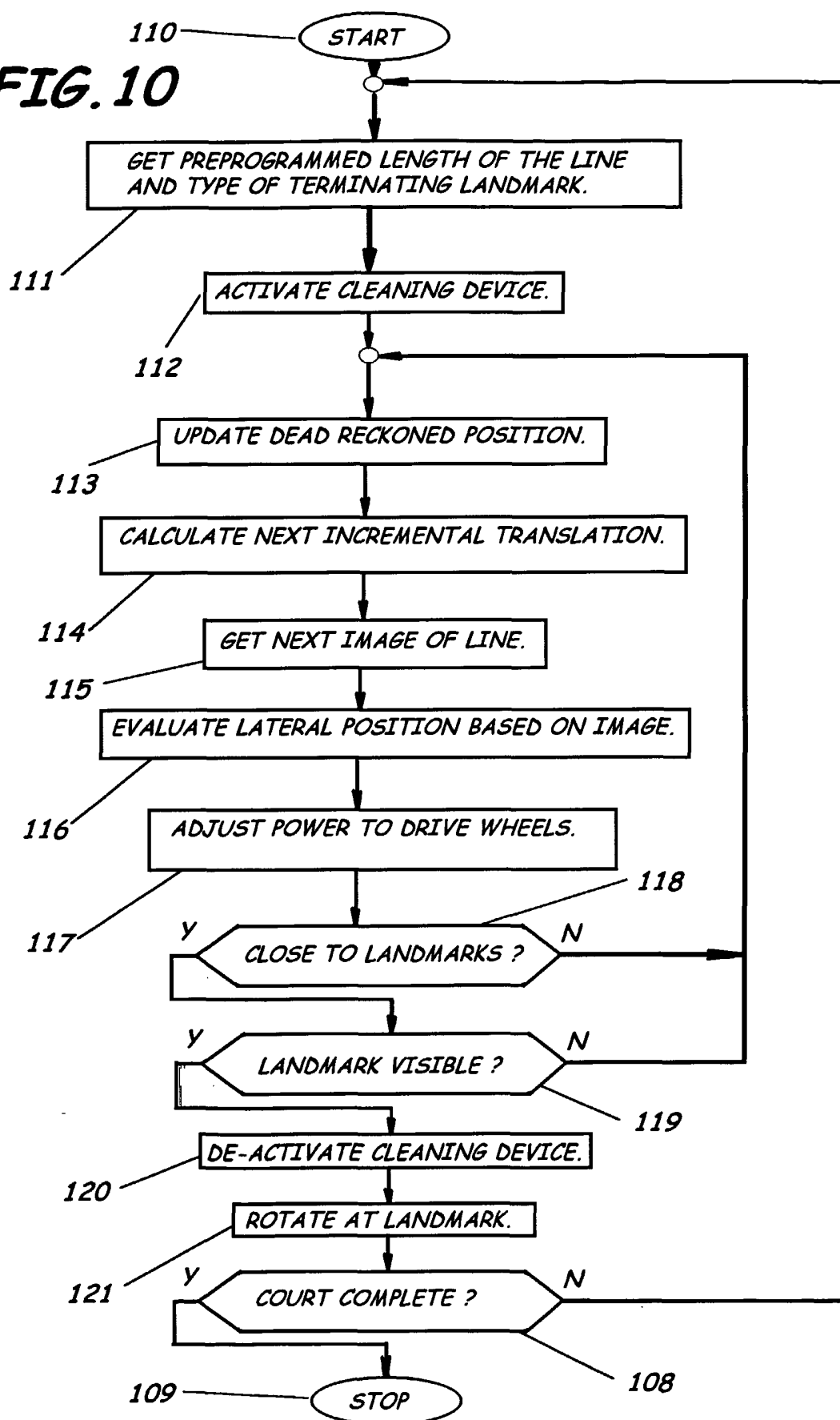
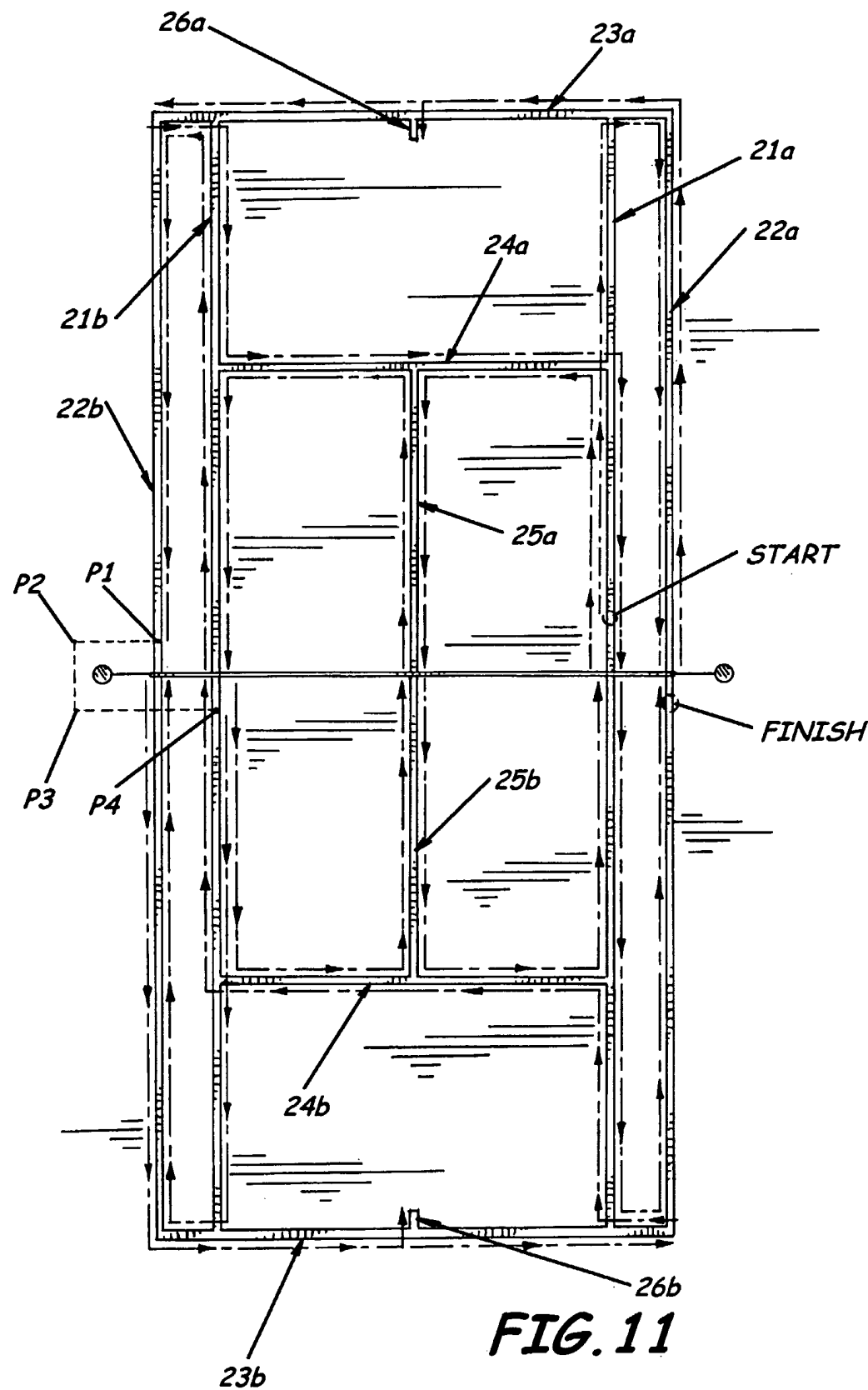


FIG. 9

FIG. 10

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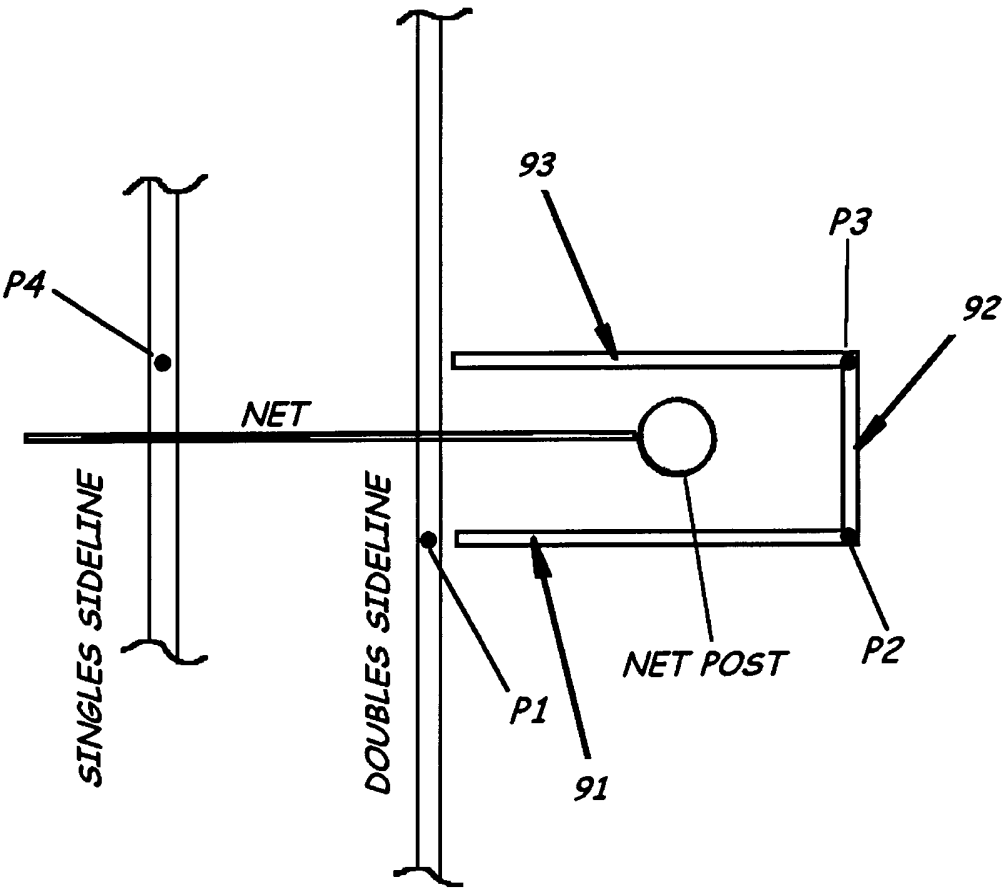
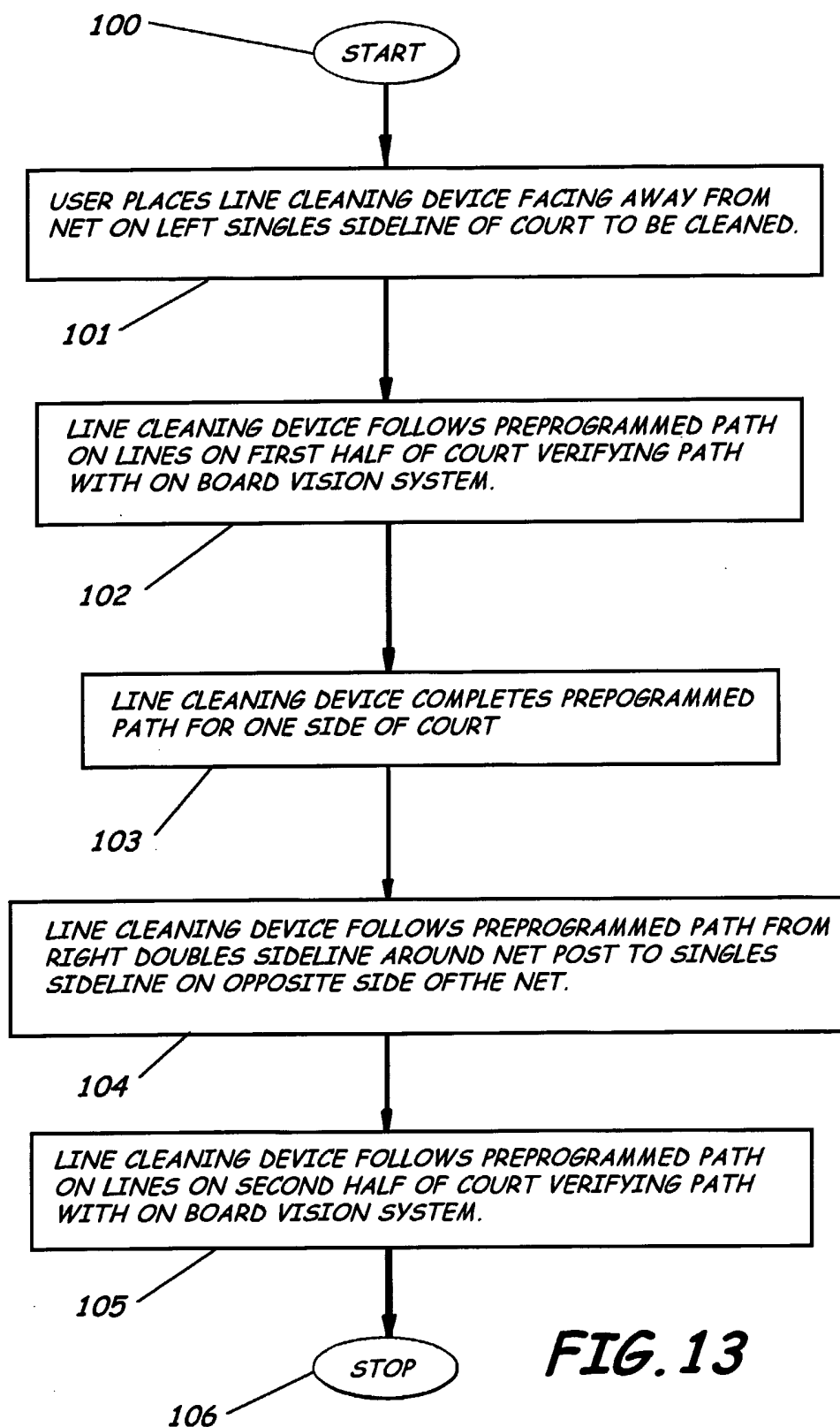


FIG.12

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**FIG. 13**

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 02/26878

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 E01H1/05 G05D1/03

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 E01H G05D

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.
X	US 3 935 922 A (COOPER JACK A ET AL) 3 February 1976 (1976-02-03)	1-7, 14, 15, 17-23, 45-47
Y	column 5, line 58 - column 6, line 25 column 6, line 52 - column 7, line 26	10, 11, 26, 27
A	column 9, line 3 - line 56; figures 1-4	30, 35, 40, 49, 53
X	FR 2 741 583 A (FERRAND CLAUDE) 30 May 1997 (1997-05-30)	1-6, 9, 12-22, 25, 28, 29
A	page 3, line 10 - line 35 page 4, line 16 - line 33; figures --- -/--	30, 35, 40, 49, 53



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

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Date of the actual completion of the international search

18 November 2002

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 02/26878

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 5 111 401 A (EVERETT JR HOBART R ET AL) 5 May 1992 (1992-05-05) column 20, line 8 - line 44; figures 8,19 ----	46,47, 50,54,55
A	US 4 958 400 A (SUGITA MASAHIKO) 25 September 1990 (1990-09-25) cited in the application the whole document -----	1,14,30, 35,40

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US 4958400	A	25-09-1990	NONE	