(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 1 427 891 B9**

(12) **CORRECTED EUROPEAN PATENT SPECIFICATION**

(15) Correction information:
Corrected version no 1 (W1 B1)
Corrections, see
Description Paragraph(s) 4, 17, 24, 26-28, 34, 37, 41, 48-49, 51
Claims EN 7-10
Numerous spelling errors of minor importance

(48) Corrigendum issued on:
10.03.2010 Bulletin 2010/10

(45) Date of publication and mention of the grant of the patent:
30.09.2009 Bulletin 2009/40

(21) Application number: **02770421.2**

(22) Date of filing: **23.08.2002**

(51) Int Cl.:
E01H 1/05 *(2006.01)* ***G05D 1/03*** *(2006.01)*

(86) International application number:
PCT/US2002/026878

(87) International publication number:
WO 2003/018913 (06.03.2003 Gazette 2003/10)

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

VORRICHTUNG UND VERFAHREN ZUM REINIGEN VON LINIEN AUF EINER SPIELFLÄCHE

APPAREIL ET PROCEDES PERMETTANT DE NETTOYER LES LIGNES D'UNE SURFACE DE JEU

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR IE IT LI LU MC NL PT SE SK TR

(30) Priority: **24.08.2001 US 314933 P**

(43) Date of publication of application:
16.06.2004 Bulletin 2004/25

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EP 1 427 891 B9

Printed by Jouve, 75001 PARIS (FR)

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to an apparatus and methods for cleaning lines on a tennis court.

2. Description of the Related Art

[0002] 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 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.

[0003] In general, a clay-surface tennis court or clay court requires daily maintenance in the form of smoothing and watering. The smoothing process is typically performed by dragging a 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.

[0004] Devices for tracking an invisible line for vehicles have been known such as shown in U.S. Patent No. 3,935,922 by Cooper et al. titled "Vehicle Guidance Mechanism.". This document discloses a device that could be used to clean a line of a tennis court even though this special use is not disclosed. Such devices, however, fail to recognise problems associated with cleaning tennis court lines, and fail to teach cleaning lines on a tennis court. Also, devices have been known for cleaning roadways and airport runways such as shown in U.S. Patent No. 5,015,300 by Leers titled "*Method and Apparatus For Adjusting A Preselected Sweeping Surface Width Of A Revolving Roll-Type Brush*". Such devices, however, also fail to relate to tennis courts, fail to recognise problems associated with cleaning tennis court lines, and fail to teach cleaning lines on a tennis court.

[0005] Instead, the cleaning of tennis court lines commonly is performed by a person walking a roller 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.

SUMMARY OF THE INVENTION

[0006] The present invention provides an apparatus and a method for enhancing the cleaning of boundary lines on a playing surface which substantially reduces or eliminates the manual labour involved in caring for the playing surface and which reduces the time involved in caring for a playing surface. The cleaning apparatus senses 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 labour. Computer program code means indicative of the familiarity or dimensions of a playing surface, such as a clay-surface tennis court, are stored in a memory, and direct the cleaning of the boundary lines of the tennis court by sensing means sensing the presence of or a location of the boundary lines.

[0007] More particularly, the present invention provides an apparatus for cleaning a line on a surface, said apparatus having a chassis, a sensing device connected to the chassis to sense a location of the line, a drive connected to the chassis to drive the chassis in a selected direction of travel along the line, a controller connected to the chassis, in communication with the drive, and responsive to the sensing device to control the drive to thereby direct the chassis to be driven along the line in the selected direction of travel, and a cleaning device connected to the chassis being positioned to clean the line when the chassis is being driven along the line, the cleaning device including a cleaning tool, the apparatus being **characterized in that**:

[0008] the apparatus is adapted for cleaning lines on a tennis court surface by the controller including a memory having computer program code means stored therein, the computer program code means being indicative of a set of predetermined boundary line parameters, a set of drive parameters and a set of tennis court surface parameters; and in that

[0009] the apparatus is further adapted for cleaning lines on a tennis court surface by a tool lift assembly that is connected to the cleaning tool to selectively raise the cleaning tool from and lower the cleaning tool to the tennis court surface responsive to the computer program code means stored in the memory of the controller.

[0010] The present invention also provides a method of cleaning boundary lines on a tennis court surface. The method for cleaning boundary lines on a tennis court surface includes directing the cleaning apparatus to move along boundary lines on a tennis court surface responsive to a set of programmed directions, and cleaning the boundary lines when the cleaning device is moving along the boundary lines, while selectively positioning a cleaning tool on a boundary line to clean the boundary line as the cleaning device is moving over the boundary line.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] 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:

[0012] **FIG. 1** is an environmental view of a cleaning apparatus being used for cleaning lines on the playing surface of a tennis court according to an embodiment of the present invention;

[0013] **FIG. 2** is a perspective view of a cleaning apparatus according to an embodiment of FIG. 1 of the present invention;

[0014] **FIG. 3** is a perspective view of a cleaning apparatus according to another embodiment of the present invention;

[0015] **FIG. 4** is a perspective view of a cleaning apparatus according to yet another embodiment of the present invention;

[0016] **FIG. 5** is a bottom plan view of a cleaning apparatus according to the embodiment of FIG. 3 of the present invention;

[0017] **FIG. 6** is a side elevational view of a cleaning apparatus according to the embodiment of FIG. 3 of the present invention;

[0018] **FIG. 7** is a block diagram of a cleaning apparatus according to an embodiment of the present invention;

[0019] **FIG. 8** is a schematic diagram of a line-sensing module within a cleaning apparatus according to an embodiment of the present invention;

[0020] **FIG. 9** is a schematic diagram of a propulsion module within the cleaning apparatus according to an embodiment of the present invention;

[0021] **FIG. 10** is a flowchart illustrating operation of a cleaning apparatus and associated software and methods according to an embodiment of the present invention;

[0022] **FIG. 11** is a top plan view of a cleaning route on a tennis court, in accordance with an embodiment of the present invention;

[0023] **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

[0024] **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

[0025] 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 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, indicate similar elements in alternative embodiments.

[0026] 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 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 about 8.30 meters (27 feet) by about 23.77 meters (78 feet), and the size of a standard double's court is defined as about 10.97 meters (36 feet) by about 23.77 meters (78 feet). The size of a standard service court is defined as about 8.30 meters (27 feet) by about 12.80 meters (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 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.

[0027] FIGS. 2-7 illustrate a cleaning apparatus **30**, in accordance with three different embodiments of the present invention. As shown, the cleaning 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,** 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 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 appa-

ratus **30, 130, 230** to be sensed. The sense data information obtained by the line-sensing module **31** is communicated to the navigation and control module **32** 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 **32** determines the position of the cleaning apparatus **30** in relation to the detected landmark on the tennis court **20**, and then controls the propulsion module or drive **33** 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 game playing surface. The propulsion or drive module **33** 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 **36** and a swivel wheel **37**. The cleaning device **34** 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 include a cleaning a brush 61, 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** 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 surrounding the boundary lines.

[0028] **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** position 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** is 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.

[0029] 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.

[0030] 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.

[0031] 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.

[0032] 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).

[0033] 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).

[0034] 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 in direct contact with the boundary line, the navigation and control module **32** deactivates 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 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). 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 activating the cleaning device **34** in the proximity (the exact position may not be known because of accumulated error) of a boundary line to correct 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.**

[0035] **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.

[0036] 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 controlled by 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 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** pre-

cisely on the 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.

[0037] As explained previously, the cleaning device **34** can be one of a number of mechanisms for removing debris from a boundary line. The 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 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 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.

[0038] 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 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 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 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.**

[0039] The brush assembly hoist mechanism **65** is an example of the 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 encountered by the drive wheels **36.**

[0040] 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 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 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 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 (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** is not in contact with the court surface.

[0041] The tennis court **20** can be divided into two half courts, one on each side of the net. The algorithm for cleaning boundary lines involves working the first side of the tennis court **20** and then crossing 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 are 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 **12a** 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**.

[0042] The apparatus 30 cleans the service line **24a** from the single's sideline **21b** to the single's sideline **21a** and stops at the singles 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 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 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.

[0043] 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.

[0044] 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 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.

[0045] 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.

[0046] 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.**

[0047] 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.

[0048] 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 used to navigate the cleaning apparatus **30** through the rest of the way to point **P4.**

[0049] 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 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 **20,** albeit outside the boundaries of play, but the first method described works on any regulation tennis court without any modification at all.

[0050] 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 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 **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 the path with the on-board line-sensing module, as shown in block **105.**

[0051] **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 show 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**.

[0052] 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**.

[0053] 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 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 is the 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 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.

[0054] Another method for cleaning boundary lines on a game playing surface can include 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. 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 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 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.

[0055] 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 net 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 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 cleaning the boundary lines on the second 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 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 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.

[0056] The apparatus, as described and illustrated, also includes software or 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 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 is the surface of a tennis court.

[0057] Another computer program product for cleaning boundary lines on a game playing surface 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 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 can further use wheel dimensions and rotation data and a predetermined length of each boundary line. The game playing surface is the surface of a tennis court.

[0058] Still another 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, 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 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. 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 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 is a tennis court as illustrated and described.

Claims

1. An apparatus (30) for cleaning a line on a surface, said apparatus having a chassis (35), a sensing device (31) connected to the chassis (35) to sense a location of the line, a drive (33) connected to the chassis (35) to drive the chassis (35) in a selected direction of travel along the line, a controller (32) connected to the chassis (35), in communication with the drive (33), and responsive to the sensing device (31) to control the drive (33) to thereby direct the chassis (35) to be driven along the line in the selected direction of travel, and a cleaning device (34) connected to the chassis (35) being positioned to clean the line when the chassis (35) is being driven along the line, the cleaning device (34) including a cleaning tool (61), the apparatus (30) being **characterized in that:**

the apparatus (30) is adapted for cleaning lines (21a-21b, 22a-22b, 23a-23b, 24a-24b, 25a-25b) on a tennis court surface (20) by the controller (32) including a memory having computer program code means stored therein, the computer program code means being indicative of a set of predetermined boundary line parameters, a set of drive parameters and a set of tennis court surface parameters; and **in that**

the apparatus (30) is further adapted for cleaning lines (21a-21b, 22a-22b, 23a-23b, 24a-24b, 25a-25b) on a tennis court surface (20) by a tool lift assembly that is connected to the cleaning tool (61) to selectively raise the cleaning tool from and lower the cleaning tool to the tennis court surface (20) responsive to the computer program code means stored in the memory of the controller (32).

2. An apparatus (30) as defined in Claim 1, wherein the sensing device (31) is further positioned at an elevation higher than the tennis court surface (20) and oriented to capture an image in a direction transverse to the tennis court surface (20) and comprises an optical sensing device (42), the optical sensing device (42) including at least one sensor (43) and at least one lens (44), the at least one sensor (43) having a plurality of photodiodes (41) positioned to capture an image received through the lens (44), the optical sensing device (42) also including a sensor interface (47) positioned to serially shift out the captured image defined as a plurality of pixels, each of the plurality of pixels having a brightness level represented by at least one voltage signal received over a controlled period of time.

3. An apparatus (30) as defined in Claim 2, wherein the controller (32) includes a line determiner positioned to determine whether a boundary line is present based on the captured image and a position analyzer responsive to the line determiner to analyze the captured image received from the sensor interface (47) so that a lateral position of the chassis (35) is provided to the drive and so that a field of view of the sensing device (31) is oriented on the boundary line (21a-21b, 22a-22b, 23a-23b, 24a-24b, 25a-25b), and wherein the controller (32) further reduces a drive speed of the drive to slow down the chassis (35) responsive to the set of predetermined parameters when the chassis (35) approaches an end of the boundary line (21a-21b, 22a-22b, 23a-23b, 24a-24b, 25a-25b) to be cleaned.

4. An apparatus (30) as defined in Claim 2 or 3, wherein the sensing device (31) further includes an array of illuminators positioned to illuminate the tennis court surface (20) for the optical sensing device (42).

5. An apparatus (30) as defined in Claim 1, 2, 3, or 4, wherein the sensing device (31) is positioned on the chassis (35) downstream from the cleaning device (34) as the cleaning device (34) is being driven along the direction of travel.

6. An apparatus (30) as defined in Claim 1, 2, 3, 4, or 5, wherein the drive (33) comprises at least two drive wheels (36a, 36b) and a differential drive (51a, 51b) connected to each of the at least two drive wheels (36a, 36b) and positioned to independently drive each of the at least two drive wheels (36a, 36b) so that a position of the chassis (35) when being driven along the boundary line is compensated to enhance orientation of the chassis (35) along the boundary line (21a-21b, 22a-22b, 23a-23b, 24a-24b, 25a-25b).

7. An apparatus (30) as defined in Claim 1, 2, 3, 4, 5 or 6, wherein the cleaning device (34) further includes a frame connected to the chassis (35) and to the cleaning tool (61), a height control wheel (62) connected to the frame to control the positional distance of the cleaning tool (61) from the tennis court surface (20), and a tool drive motor (63) connected to the frame and responsive to the controller (32) to selectively drive the cleaning tool (61).

8. An apparatus (30) as defined in Claim 1, 2, 3, 4, 5, 6 or 7, wherein the set of predetermined parameters of which the computer program code means stored in the memory of the controller (32) is indicative, further includes a known initial position of the chassis (35) and operational parameters of the cleaning device (34), wherein the set of predetermined drive parameters incudes wheel dimension and rotation data, and wherein the set of predetermined line parameters includes a predetermined length of each boundary line (21a-21b, 22a-22b, 23a-23b, 24a-24b, 25a-25b) on the tennis court surface (20).

9. An apparatus (30) as defined in Claim 1, 2, 3, 4, 5, 6, 7 or 8, wherein the tennis court surface (20) includes a first playing surface and a second playing surface separated from each other by a net connected between a plurality of posts, and wherein the controller (32) further directs the cleaning device (34) to move abound one of the net posts from the first playing surface to position the cleaning device (34) on the second playing surface.

10. A method for cleaning boundary lines (21a-21b, 22a-22b, 23a-23b, 24a-24b, 25a-25b) on a tennis court surface (20), the method comprising:

directing a cleaning device (34) having a cleaning tool (61) to move along a plurality of boundary lines (21a-21b, 22a-22b, 23a-23b, 24a-24b, 25a-25b) on a tennis court surface. (20) responsive to a set of programmed directions, the set of programmed directions including computer program code means stored in a memory of a controller (32) of the cleaning device (34), the computer program code means being indicative of a set of predetermined boundary line parameters, a set of drive parameters and a set of tennis court surface parameters;

selectively raising and lowering the cleaning tool (61) by a tool lift assembly on one of the plurality of boundary lines (21a-21b, 22a-22b, 23a-23b, 24a-24b, 25a-25b) responsive to the computer program code means stored in the memory of the controller (32) to clean the one boundary line as the cleaning device (34) is moving over the boundary line; and

cleaning the boundary lines (21a-21b, 22a-22b, 23a-23b, 24a-24b, 25a-25b) with the cleaning

tool (61) responsive to the set of programmed directions when the cleaning device (34) is moving along the one boundary line (21a-21b, 22a-22b, 23a-23b, 24a-24b, 25a-25b).

11. A method as defined in Claim 10, wherein the directing step further includes a step of determining a current position of the cleaning device (34) by using a known initial position and an orientation of the cleaning device (34) on the tennis court surface (20).

12. A method as defined in Claim 11, wherein the determining step further uses wheel dimensions and rotation data and a predetermined length of each boundary line (21a-21b, 22a-22b, 23a-23b, 24a-24b, 25a-25b).

13. A method as defined in Claim 10, 11, or 12, wherein the directing step includes following a plurality of preselected tracking guidelines situated around a net post of the tennis court surface (20) for guiding the cleaning device (34) to move around the net post.

14. A method as defined in Claim 10, 11, 12, or 13, further comprising sensing a location of a boundary line (21a-21b, 22a-22b, 23a-23b, 24a-24b, 25a-25b) of a tennis court surface (20).

15. A method as defined in Claim 10, 11, or 12, wherein the tennis court surface (20) 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 further comprising:

directing the cleaning device (34) to move along the boundary lines (21a-21b, 22a-22b, 23a-23b, 24a-24b, 25a-25b) on the first playing surface responsive to the set of programmed directions;
cleaning the boundary lines (21a-21b, 22a-22b, 23a-23b, 24a-24b, 25a-25b) on the first playing surface as the cleaning device (34) is moving over the boundary lines (21a-21b, 22a-22b, 23a-23b, 24a-24b, 25a-25b) on the first playing surface;
directing the cleaning device (34) to move around one of the net posts to position the cleaning device on the second playing surface; and
cleaning the boundary lines (21a-21b, 22a-22b, 23a-23b, 24a-24b, 25a-25b) on the second playing surface as the cleaning device (34) is moving over the boundary lines (21a-21b, 22a-22b, 23a-23b, 24a-24b, 25a-25b) on the second playing surface.

Patentansprüche

1. Vorrichtung (30) zum Reinigen einer Linie auf einer Oberfläche, wobei die Vorrichtung ein Fahrgestell (35), eine Erfassungsvorrichtung (31), die mit dem Fahrgestell (35) verbunden ist, um eine Lage einer Linie zu erfassen, einen Antrieb (33), der mit dem Fahrgestell (35) verbunden ist, um das Fahrgestell (35) in einer ausgewählten Fortbewegungsrichtung entlang der Linie anzutreiben, eine Steuerung (32), die mit dem Fahrgestell (35) verbunden ist und mit dem Antrieb (33) in Kommunikation ist sowie auf die Erfassungsvorrichtung (31) anspricht, um den Antrieb (33) zu steuern, um **dadurch** das Fahrgestell (35) so zu lenken, dass es entlang der Linie in der ausgewählten Fortbewegungsrichtung angetrieben wird, und eine Reinigungsvorrichtung (34), die mit dem Fahrgestell (35) verbunden ist, das dazu angeordnet ist, die Linie zu reinigen, wenn das Fahrgestell (35) entlang der Linie angetrieben wird, aufweist, wobei die Reinigungsvorrichtung (34) ein Reinigungswerkzeug (61) aufweist, wobei die Vorrichtung (30) **dadurch gekennzeichnet ist, dass**

- die Vorrichtung (30) dazu ausgelegt ist, Linien (21 a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) auf einer Tennisplatzoberfläche (20) **dadurch** zu reinigen, dass die Steuerung (32) einen Speicher enthält, in dem ein Computerprogrammcodemittel gespeichert ist, wobei das Computerprogrammcodemittel einen Satz vorbestimmter Grenzlinienparameter, einen Satz Antriebsparameter und einen Satz Tennisplatzoberflächenparameter angibt; und **dadurch**, dass
- die Vorrichtung (30) ferner dazu ausgelegt ist, Linien (21 a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) auf einer Tennisplatzoberfläche (20) durch eine Werkzeughebeanordnung zu reinigen, die mit dem Reinigungswerkzeug (61) verbunden ist, um das Reinigungswerkzeug im Ansprechen auf das Computerprogrammcodemittel, das im Speicher der Steuerung (32) gespeichert ist, selektiv von der Tennisplatzoberfläche (20) anzuheben und es auf diese abzusenken.

2. Vorrichtung (30) nach Anspruch 1, wobei die Erfassungsvorrichtung (31) ferner in einer Höhe angeordnet ist, die höher als die Tennisplatzoberfläche (20) ist, und so ausgerichtet ist, dass sie in einer Richtung senkrecht zur Tennisplatzoberfläche (20) ein Bild aufnimmt, und eine optische Erfassungsvorrichtung (42) umfasst, wobei die optische Erfassungsvorrichtung (42) mindestens einen Sensor (43) und mindestens ein Objektiv (44) aufweist, wobei der mindestens eine Sensor (43) eine Vielzahl von Photodioden (41) aufweist, die zum Aufnehmen eines durch das Objektiv (44) empfangenen Bilds angeordnet ist, wobei die optische Erfassungsvorrichtung (42) auch eine Sensorschnittstelle (47) enthält, die

dazu angeordnet ist, das aufgenommene Bild, das als eine Vielzahl von Pixeln definiert ist, seriell weiterzuleiten, wobei jedes der Vielzahl von Pixeln einen Helligkeitspegel hat, der durch mindestens ein Spannungssignal repräsentiert wird, das über einen kontrollierten Zeitraum empfangen wird.

3. Vorrichtung (30) nach Anspruch 2, wobei die Steuerung (32) eine Linienbestimmungseinrichtung, die dazu angeordnet ist, anhand des aufgenommenen Bilds zu bestimmen, ob eine Grenzlinie vorhanden ist, und eine Positionsanalyseeinrichtung enthält, die auf die Linienbestimmungseinrichtung anspricht, um das von der Sensorschnittstelle (47) empfangene aufgenommene Bild zu analysieren, damit eine seitliche Position des Fahrgestells (35) an den Antrieb geliefert wird und damit ein Sichtfeld der Erfassungsvorrichtung (31) an der Grenzlinie (21 a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) ausgerichtet wird, und wobei die Steuerung (32) ferner im Ansprechen auf den Satz vorbestimmter Parameter eine Antriebsgeschwindigkeit des Antriebs verringert, um das Fahrgestell (35) zu verlangsamen, wenn sich das Fahrgestell (35) einem Ende der zu reinigenden Grenzlinie (21 a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) nähert.

4. Vorrichtung (30) nach Anspruch 2 oder 3, wobei die Erfassungsvorrichtung (31) ferner eine Anordnung von Beleuchtungseinrichtungen enthält, die zum Beleuchten der Tennisplatzoberfläche (20) für die optische Erfassungsvorrichtung (42) angeordnet sind.

5. Vorrichtung (30) nach Anspruch 1, 2, 3 oder 4, wobei die Erfassungsvorrichtung (31) auf dem Fahrgestell (35) hinter der Reinigungsvorrichtung (34) angeordnet ist, während die Reinigungsvorrichtung (34) entlang der Fortbewegungsrichtung angetrieben wird.

6. Vorrichtung (30) nach Anspruch 1, 2, 3, 4 oder 5, wobei der Antrieb (33) mindestens zwei Antriebsräder (36a, 36b) und einen differentiellen Antrieb (51 a, 51 b) umfasst, der jeweils mit den mindestens zwei Antriebsrädern (36a, 36b) verbunden und dazu angeordnet ist, jedes der mindestens zwei Antriebsräder (36a, 36b) unabhängig anzutreiben, so dass eine Position des Fahrgestells (35) ausgeglichen wird, wenn dieses entlang der Grenzlinie angetrieben wird, um die Ausrichtung des Fahrgestells (35) entlang der Grenzlinie (21 a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) zu verbessern.

7. Vorrichtung (30) nach Anspruch 1, 2, 3, 4, 5 oder 6, wobei die Reinigungsvorrichtung (34) ferner einen Rahmen, der mit dem Fahrgestell (35) und dem Reinigungswerkzeug (61) verbunden ist, ein Höhensteuerrad (62), das mit dem Rahmen verbunden ist, zum Steuern der Anordnungsentfernung des Reinigungswerkzeugs (61) von der Tennisplatzoberfläche (20), sowie einen Werkzeugantriebsmotor (63) enthält, der mit dem Rahmen verbunden ist und auf die Steuerung (32) anspricht, um das Reinigungswerkzeug (61) selektiv anzutreiben.

8. Vorrichtung (30) nach Anspruch 1, 2, 3, 4, 5, 6 oder 7, wobei der Satz vorbestimmter Parameter, die durch das Computerprogrammcodemittel angegeben werden, das im Speicher der Steuerung (32) gespeichert ist, ferner eine bekannte Anfangsposition des Fahrgestells (35) und Betriebsparameter der Reinigungsvorrichtung (34) enthält, wobei der Satz vorbestimmter Antriebsparameter Radabmessungen und Drehurigsdaten enthält, und wobei der Satz vorbestimmter Linienparameter eine vorbestimmte Länge einer jeden Grenzlinie (21 a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) auf der Tennisplatzoberfläche (20) enthält.

9. Vorrichtung (30) nach Anspruch 1, 2, 3, 4, 5, 6, 7 oder 8, wobei die Tennisplatzoberfläche (20) eine erste Spieloberfläche und eine zweite Spieloberfläche enthält, die von einem Netz, das an einer Vielzahl von Pfosten befestigt ist, voneinander getrennt sind, und wobei die Steuerung (32) ferner die Reinigungsvorrichtung (34) lenkt, so dass sie von der ersten Spieloberfläche um einen der Netzpfosten herum bewegt wird, um die Reinigungsvorrichtung (34) auf der zweiten Spieloberfläche zu positionieren.

10. Verfahren zum Reinigen von Grenzlinien (21 a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) auf einer Tennisplatzoberfläche (20), wobei das Verfahren umfasst:

- Lenken einer Reinigungsvorrichtung (34) mit einem Reinigungswerkzeug (61) zur Bewegung entlang einer Vielzahl von Grenzlinien (21 a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) auf einer Tennisplatzoberfläche (20) im Ansprechen auf einen Satz programmierter Anweisungen, wobei der Satz programmierter Anweisungen ein Computerprogrammcodemittel enthält, das in einem Speicher einer Steuerung (32) der Reinigungsvorrichtung (34) gespeichert ist, wobei das Computerprogrammcodemittel einen Satz vorbestimmter Grenzlinienparameter, einen Satz Antriebsparameter und einen Satz Tennisplatzoberflächenparameter angibt;
- selektives Anheben und Absenken des Reinigungswerkzeugs (61) durch eine Werkzeughebeanordnung auf einer der Vielzahl von Grenzlinien (21 a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) im Ansprechen auf das im Speicher der Steuerung (32) gespeicherte Computerprogrammcodemittel zum Reinigen der einen Grenzlinie, während sich die Reinigungsvorrich-

tung (34) über die Grenzlinie bewegt; und
- Reinigen der Grenzlinien (21 a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) mit dem Reinigungswerkzeug (61) im Ansprechen auf den Satz programmierter Anweisungen, wenn sich die Reinigungsvorrichtung (34) entlang der einen Grenzlinie (21 a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) bewegt.

11. Verfahren nach Anspruch 10, wobei der Lenkungsschritt ferner einen Schritt zum Bestimmen einer aktuellen Position der Reinigungsvorrichtung (34) durch die Verwendung einer bekannten Anfangsposition und einer Ausrichtung der Reinigungsvorrichtung (34) auf der Tennisplatzoberfläche (20) enthält.

12. Verfahren nach Anspruch 11, wobei der Bestimmungsschritt ferner Radabmessungen und Drehungsdaten sowie eine vorbestimmte Länge einer jeden Grenzlinie (21 a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) verwendet.

13. Verfahren nach Anspruch 10, 11 oder 12, wobei der Lenkungsschritt ferner das Folgen einer Vielzahl vorgewählter Führungslinien enthält, die um einen Netzpfosten der Tennisplatzoberfläche (20) herum angeordnet sind, um die Reinigungsvorrichtung (34) zu führen, damit sie sich um den Netzpfosten herum bewegt.

14. Verfahren nach Anspruch 10, 11, 12 oder 13, ferner umfassend das Erfassen einer Lage einer Grenzlinie (21 a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) einer Tennisplatzoberfläche (20).

15. Verfahren nach Anspruch 10, 11 oder 12, wobei die Tennisplatzoberfläche (20) eine erste Spieloberfläche und eine zweite Spieloberfläche enthält, die von einem Netz, das an einer Vielzahl von Pfosten befestigt ist, voneinander getrennt sind, wobei das Verfahren ferner umfasst:

- Lenken der Reinigungsvorrichtung (34) zur Bewegung entlang der Grenzlinien (21 a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) auf der ersten Spieloberfläche im Ansprechen auf den Satz programmierter Anweisungen;
- Reinigen der Grenzlinien (21 a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) auf der ersten Spieloberfläche, während sich die Reinigungsvorrichtung (34) über die Grenzlinien (21 a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) auf der ersten Spieloberfläche bewegt;
- Lenken der Reinigungsvorrichtung (34) zur Bewegung um einen der Netzpfosten herum, um die Reinigungsvorrichtung auf der zweiten Spieloberfläche zu positionieren; und
- Reinigen der Grenzlinien (21 a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) auf der zweiten Spieloberfläche, während sich die Reinigungsvorrichtung (34) über die Grenzlinien (21 a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) auf der zweiten Spieloberfläche bewegt.

Revendications

1. Appareil (30) pour nettoyer une ligne sur une surface, ledit appareil ayant un châssis (35), un dispositif de détection (31) raccordé au châssis (35) pour détecter un emplacement de la ligne, un dispositif d'entraînement (33) raccordé au châssis (35) pour entraîner le châssis (35) dans une direction de déplacement choisie le long de la ligne, un contrôleur (32) raccordé au châssis (35), en communication avec le dispositif d'entraînement (33) et sensible au dispositif de détection (31) pour contrôler le dispositif d'entraînement (33) afin de diriger le châssis (35) pour qu'il soit entraîné le long de la ligne dans la direction de déplacement choisie, et un dispositif de nettoyage (34) raccordé au châssis (35) qui est positionné pour nettoyer la ligne lorsque le châssis (35) est entraîné le long de la ligne, le dispositif de nettoyage (34) comprenant un outil de nettoyage (61), l'appareil (30) étant **caractérisé en ce que :**

l'appareil (30) est adapté pour nettoyer des lignes (21a - 21b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) sur une surface de court de tennis (20) par le contrôleur (32) comprenant une mémoire ayant des moyens de code de programme informatique stockés dans celle-ci, les moyens de code de programme informatique indiquant un ensemble de paramètres de lignes de délimitation prédéterminés, un ensemble de paramètres d'entraînement et un ensemble de paramètres de surface de court de tennis ; et **en ce que** :
l'appareil (30) est en outre adapté pour nettoyer des lignes (21 a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) sur une surface de court de tennis (20) par un ensemble de levage d'outil qui est raccordé à l'outil de nettoyage (61) pour lever sélectivement l'outil de nettoyage de et abaisser l'outil de nettoyage sur la surface de court de tennis (20) en réponse aux moyens de code de programme informatique stockés dans la mémoire du contrôleur (32).

2. Appareil (30) selon la revendication 1, dans lequel le dispositif de détection (31) est en outre positionné à une hauteur plus haute que la surface du court de tennis (20) et orienté pour capturer une image dans une direction transversale par rapport à la surface du court de tennis (20) et comprend un dispositif de

détection optique (42), le dispositif de détection optique (42) comprenant au moins un capteur (43) et au moins une lentille (44), le au moins un capteur (43) ayant une pluralité de photodiodes (41) positionnées pour capturer une image reçue par le biais de la lentille (44), le dispositif de détection optique (42) comprenant également une interface de capteur (47) positionnée pour extraire en série l'image capturée définie comme une pluralité de pixels, chacun de la pluralité de pixels ayant un niveau de luminosité représenté par au moins un signal de tension reçu sur une période de temps contrôlée.

3. Appareil (30) selon la revendication 2, dans lequel le contrôleur (32) comprend un déterminateur de ligne positionné pour déterminer si une ligne de délimitation est présente en fonction de l'image capturée et un analyseur de position sensible au déterminateur de ligne pour analyser l'image capturée reçue par l'interface de capteur (47) de sorte qu'une position latérale du châssis (35) est fournie au dispositif d'entraînement et de sorte qu'un champ de vision du dispositif de détection (31) est orienté sur la ligne de délimitation (21a - 21b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b), et dans lequel le contrôleur (32) réduit en outre une vitesse d'entraînement du dispositif d'entraînement pour ralentir le châssis (35) en réponse à l'ensemble de paramètres prédéterminés lorsque le châssis (35) s'approche d'une extrémité de la ligne de délimitation (21 a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) à nettoyer.

4. Appareil (30) selon la revendication 2 ou 3, dans lequel le dispositif de détection (31) comprend en outre un ensemble d'illuminateurs positionnés pour éclairer la surface du court de tennis (20) pour le dispositif de détection optique (42).

5. Appareil (30) selon la revendication 1, 2, 3 ou 4, dans lequel le dispositif de détection (31) est positionné sur le châssis (35) en aval du dispositif de nettoyage (34) lorsque le dispositif de nettoyage (34) est entraîné le long de la direction de déplacement.

6. Appareil (30) selon la revendication 1, 2, 3, 4 ou 5, dans lequel le dispositif d'entraînement (33) comprend au moins deux roues motrices (36a, 36b) et un entraînement différentiel (51a, 51b) raccordé à chacune des au moins deux roues motrices (36a, 36b) et positionné pour entraîner indépendamment chacune des au moins deux roues motrices (36a, 36b), de sorte qu'une position du châssis (35), lorsqu'il est entraîné le long de la ligne de délimitation, est compensée afin d'améliorer l'orientation du châssis (35) le long de la ligne de délimitation (21a - 21b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b).

7. Appareil (30) selon la revendication 1, 2, 3, 4, 5 ou 6, dans lequel le dispositif de nettoyage (34) comprend en outre un cadre raccordé au châssis (35) et à l'outil de nettoyage (61), une roulette de réglage de hauteur (62) raccordée au cadre afin de contrôler la distance de positionnement de l'outil de nettoyage (61) par rapport à la surface du court de tennis (20), et un moteur d'entraînement d'outil (63) raccordé au cadre et sensible au contrôleur (32) pour entraîner sélectivement l'outil de nettoyage (61).

8. Appareil (30) selon la revendication 1, 2, 3, 4, 5, 6 ou 7, dans lequel l'ensemble de paramètres prédéterminés dont les moyens de code de programme informatique stockés dans la mémoire du contrôleur (32) sont indicatifs, comprend en outre une position initiale connue du châssis (35) et des paramètres de fonctionnement du dispositif de nettoyage (34), dans lequel l'ensemble de paramètres d'entraînement prédéterminés comprend des données de dimension et de rotation de roue, et dans lequel l'ensemble de paramètres de ligne prédéterminés comprend une longueur prédéterminée de chaque ligne de délimitation (21a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) sur la surface du court de tennis (20).

9. Appareil (30) selon la revendication 1, 2, 3, 4, 5, 6, 7 ou 8, dans lequel la surface de court de tennis (20) comprend une première surface de jeu et une seconde surface de jeu séparées l'une de l'autre par un filet raccordé entre une pluralité de poteaux, et dans lequel le contrôleur (32) dirige en outre le dispositif de nettoyage (34) pour se déplacer autour de l'un des poteaux de filet à partir de la première surface de jeu afin de positionner le dispositif de nettoyage (34) sur la seconde surface de jeu.

10. Procédé pour nettoyer des lignes de délimitation (21a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) sur une surface de court de tennis (20), le procédé comprenant les étapes consistant à :

diriger un dispositif de nettoyage (34) ayant un outil de nettoyage (61) pour se déplacer le long d'une pluralité de lignes de délimitation (21a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) sur une surface de court de tennis (20) en réponse à un ensemble de directions programmées, l'ensemble de directions programmées comprenant des moyens de code de programme informatique stockés dans une mémoire d'un contrôleur (32) du dispositif de nettoyage (34), les moyens de code de programme informatique étant indicatifs d'un ensemble de paramètres de lignes de délimitation prédéterminés, d'un ensemble de paramètres d'entraînement et d'un ensemble de paramètres de surface de court de tennis ;
lever et abaisser sélectivement l'outil de net-

toyage (61) avec un ensemble de levage d'outil sur l'une de la pluralité de lignes de délimitation (21a - 21b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) en réponse aux moyens de code de programme informatique stockés dans la mémoire du contrôleur (32) pour nettoyer la une ligne de délimitation lorsque le dispositif de nettoyage (34) se déplace sur la ligne de délimitation ; et

nettoyer les lignes de délimitation (21a - 21b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) avec l'outil de nettoyage (61) en réponse à l'ensemble de directions programmées lorsque le dispositif de nettoyage (34) se déplace le long de la une ligne de délimitation (21a - 21b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b).

11. Procédé selon la revendication 10, dans lequel l'étape de direction comprend en outre une étape consistant à déterminer une position actuelle du dispositif de nettoyage (34) en utilisant une position initiale connue et une orientation du dispositif de nettoyage (34) sur la surface du court de tennis (20).

12. Procédé selon la revendication 11, dans lequel l'étape de détermination utilise en outre les données de dimension et de rotation de roue et une longueur prédéterminée de chaque ligne de délimitation (21 a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b).

13. Procédé selon la revendication 10, 11 ou 12, dans lequel l'étape de direction comprend l'étape consistant à suivre une pluralité de lignes de guidage directrices présélectionnées situées autour d'un poteau de filet de la surface de court de tennis (20) pour guider le dispositif de nettoyage (34) afin de se déplacer autour du poteau de filet.

14. Procédé selon la revendication 10, 11, 12 ou 13, comprenant en outre l'étape consistant à détecter un emplacement d'une ligne de délimitation (21 a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) d'une surface de court de tennis (20).

15. Procédé selon la revendication 10, 11 ou 12, dans lequel la surface de court de tennis (20) comprend une première surface de jeu et une seconde surface de jeu séparées l'une de l'autre par un filet raccordé entre une pluralité de poteaux, le procédé comprenant en outre les étapes consistant à :

diriger le dispositif de nettoyage (34) pour se déplacer le long des lignes de délimitation (21a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) sur la première surface de jeu en réponse à l'ensemble de directions programmées ;

nettoyer les lignes de délimitation (21a - 21b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) sur la première surface de jeu lorsque le dispositif de nettoyage (34) se déplace sur les lignes de délimitation (21a - 21b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) sur la première surface de jeu ;

diriger le dispositif de nettoyage (34) pour se déplacer autour de l'un des poteaux de filet afin de positionner le dispositif de nettoyage sur la seconde surface de jeu ; et

nettoyer les lignes de délimitation (21 a - 21 b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) sur la seconde surface de jeu lorsque le dispositif de nettoyage (34) se déplace sur les lignes de délimitation (21a - 21b, 22a - 22b, 23a - 23b, 24a - 24b, 25a - 25b) sur la seconde surface de jeu.

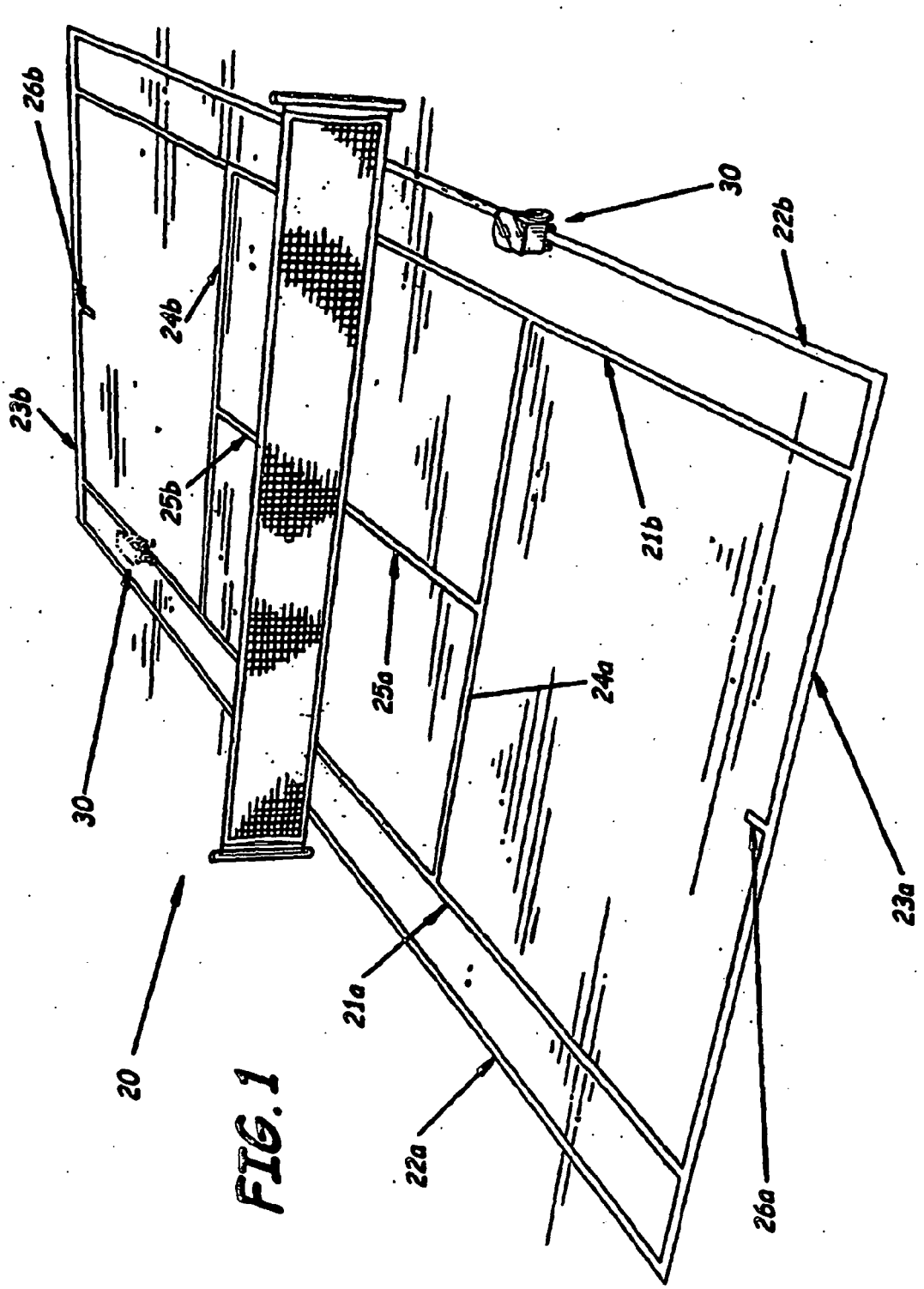
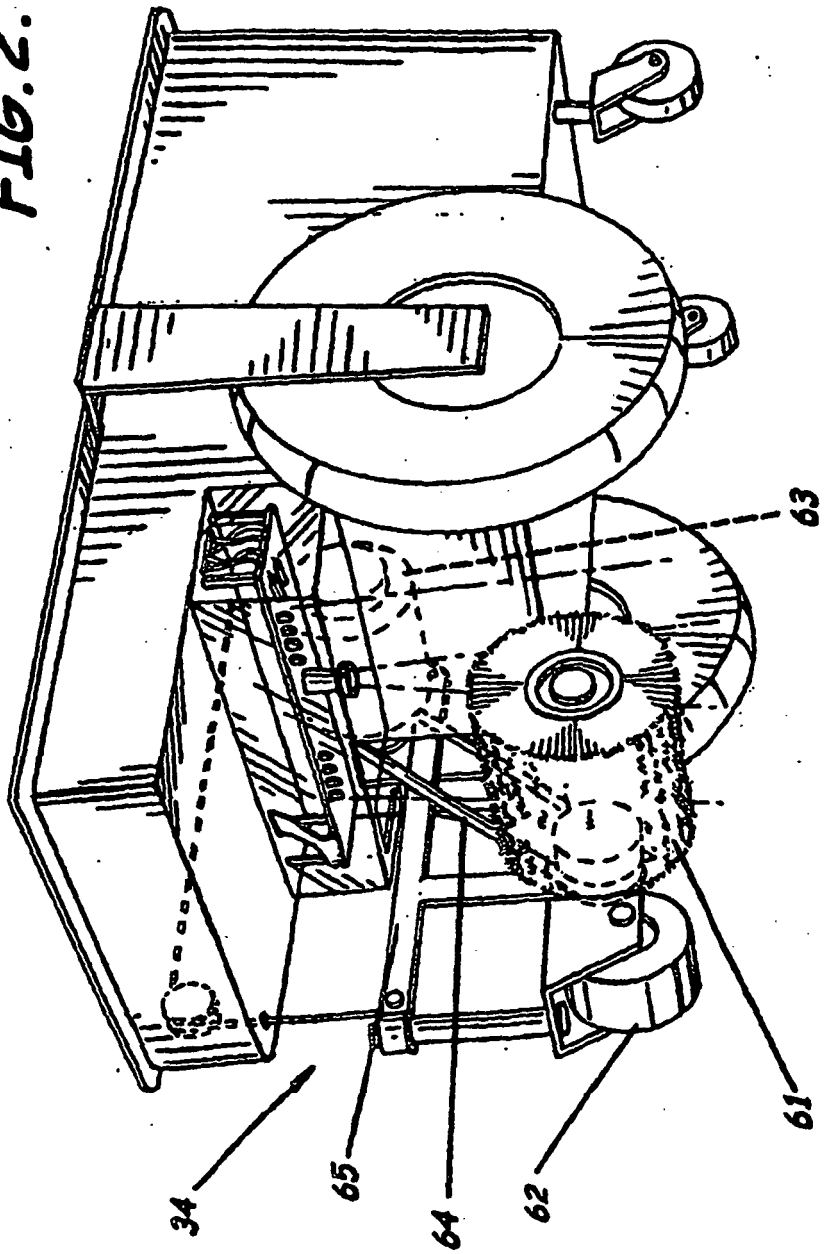


FIG. 1

FIG. 2.



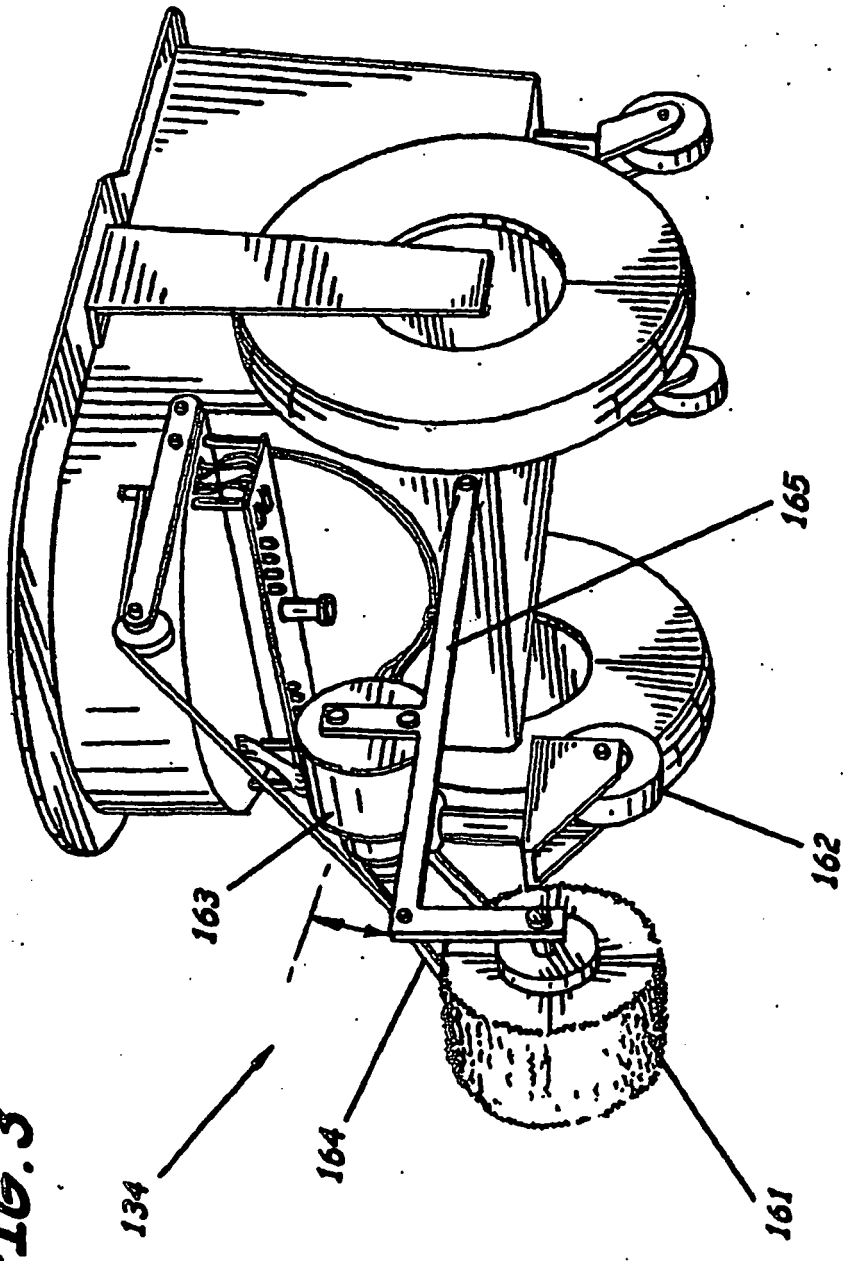


FIG. 3

FIG. 4

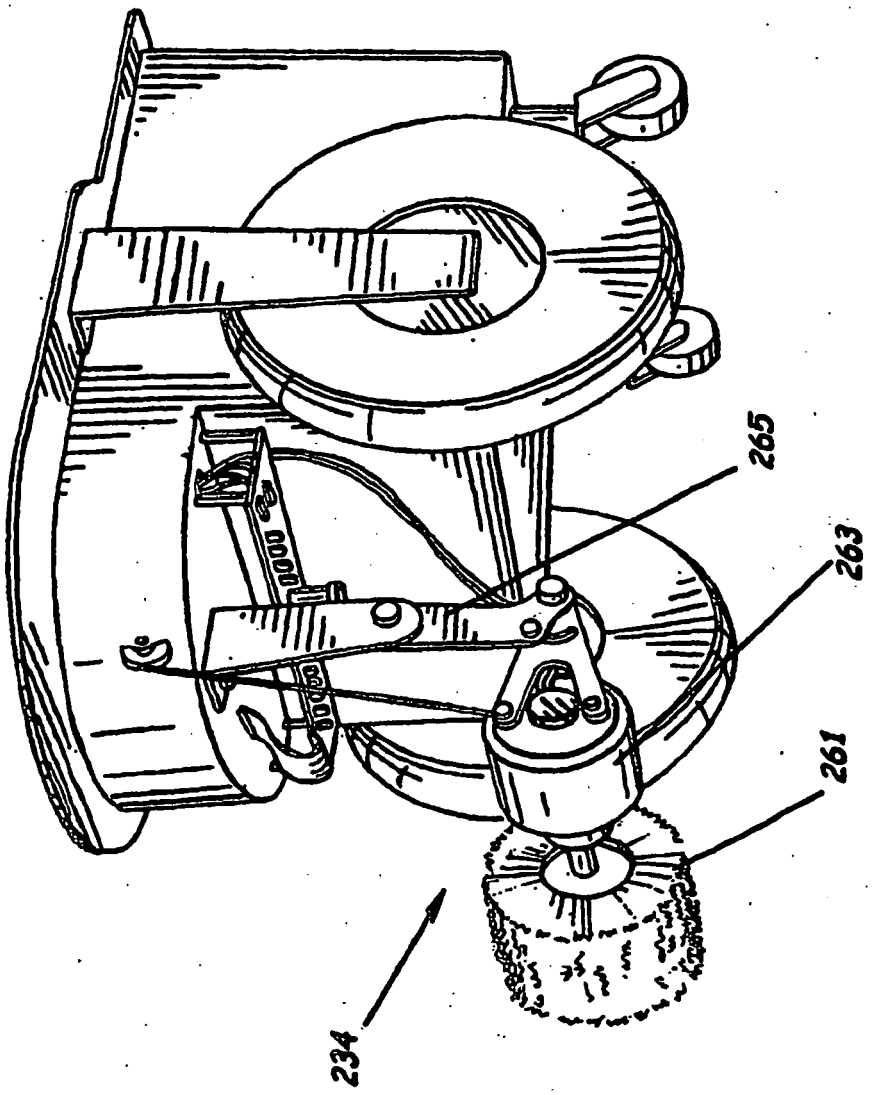


FIG. 5

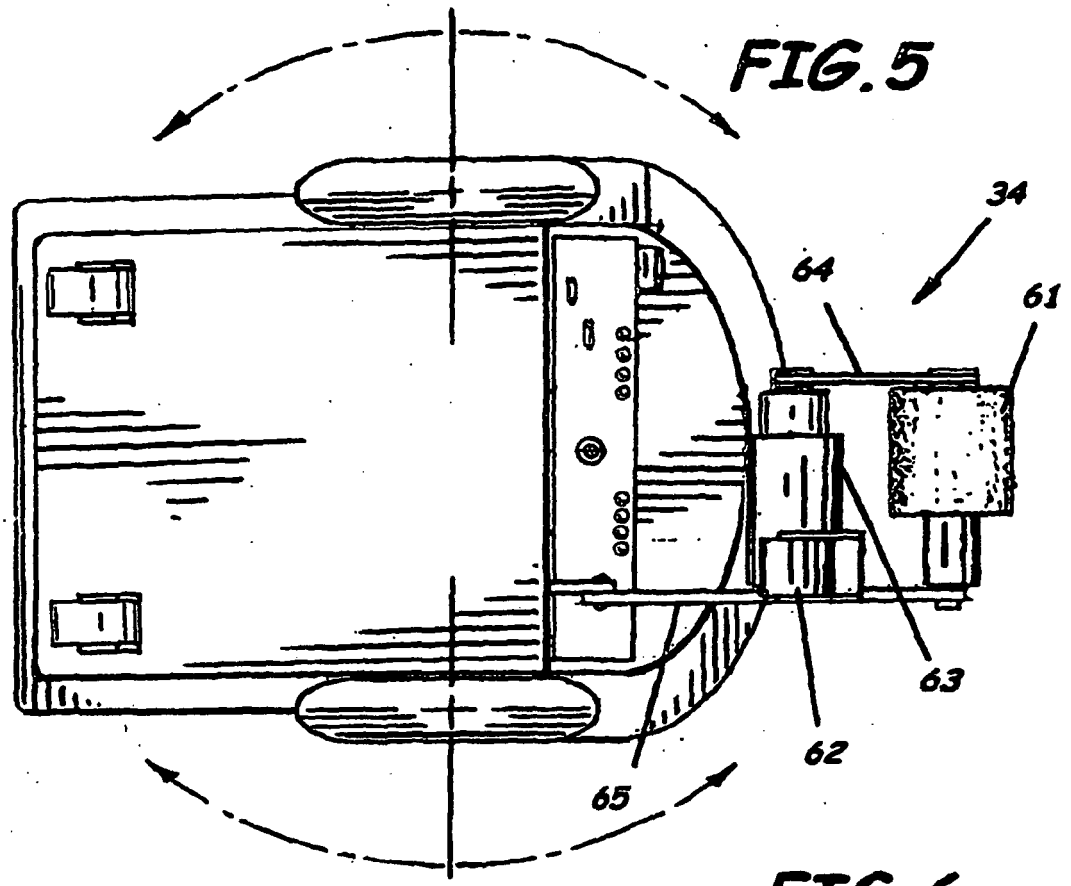
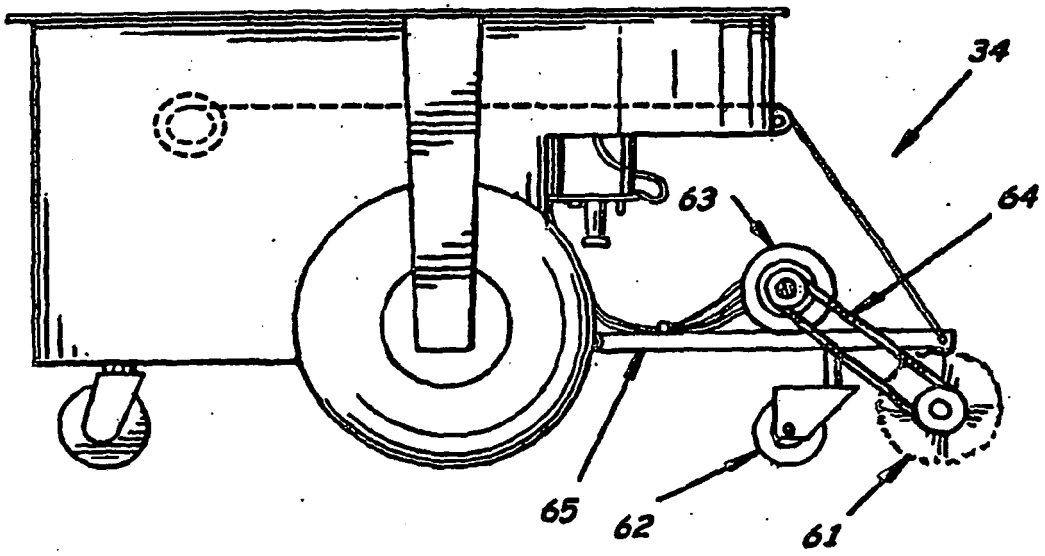


FIG. 6



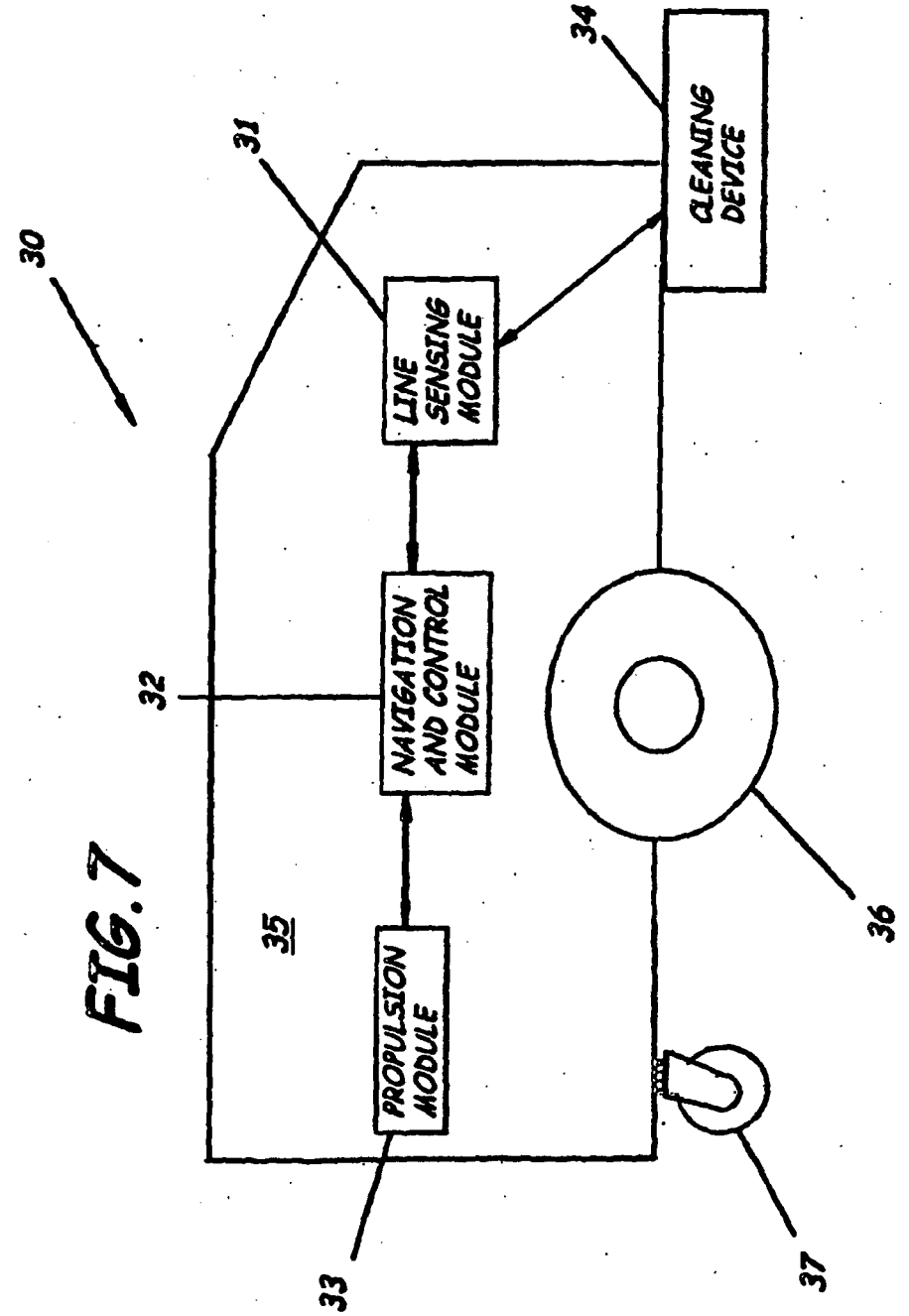

30
31
34
CLEANING DEVICE
LINE SENSING MODULE
NAVIGATION AND CONTROL MODULE
32
35
PROPULSION MODULE
33
36
37

FIG. 7

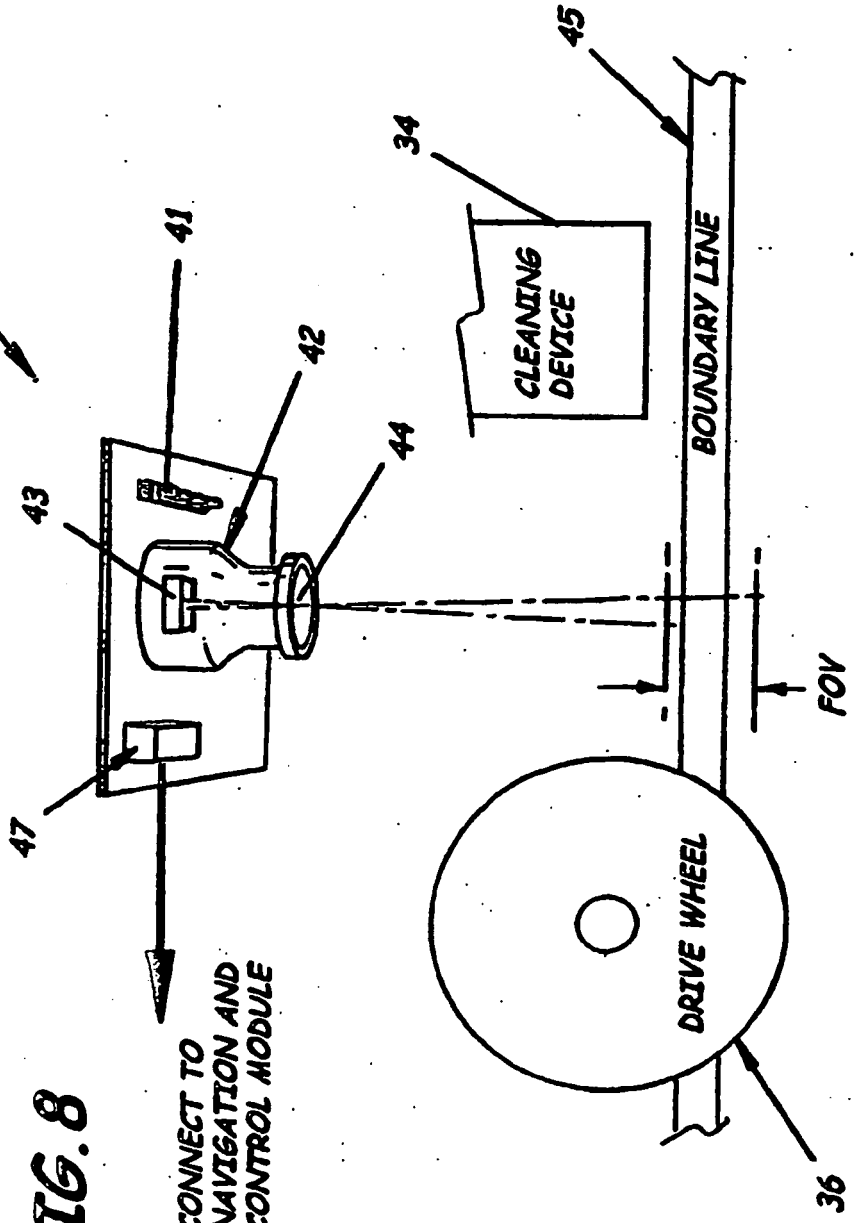

31
41
42
43
44
45
34
CLEANING DEVICE
BOUNDARY LINE
FOV
47
CONNECT TO NAVIGATION AND CONTROL MODULE
DRIVE WHEEL
36

FIG. 8

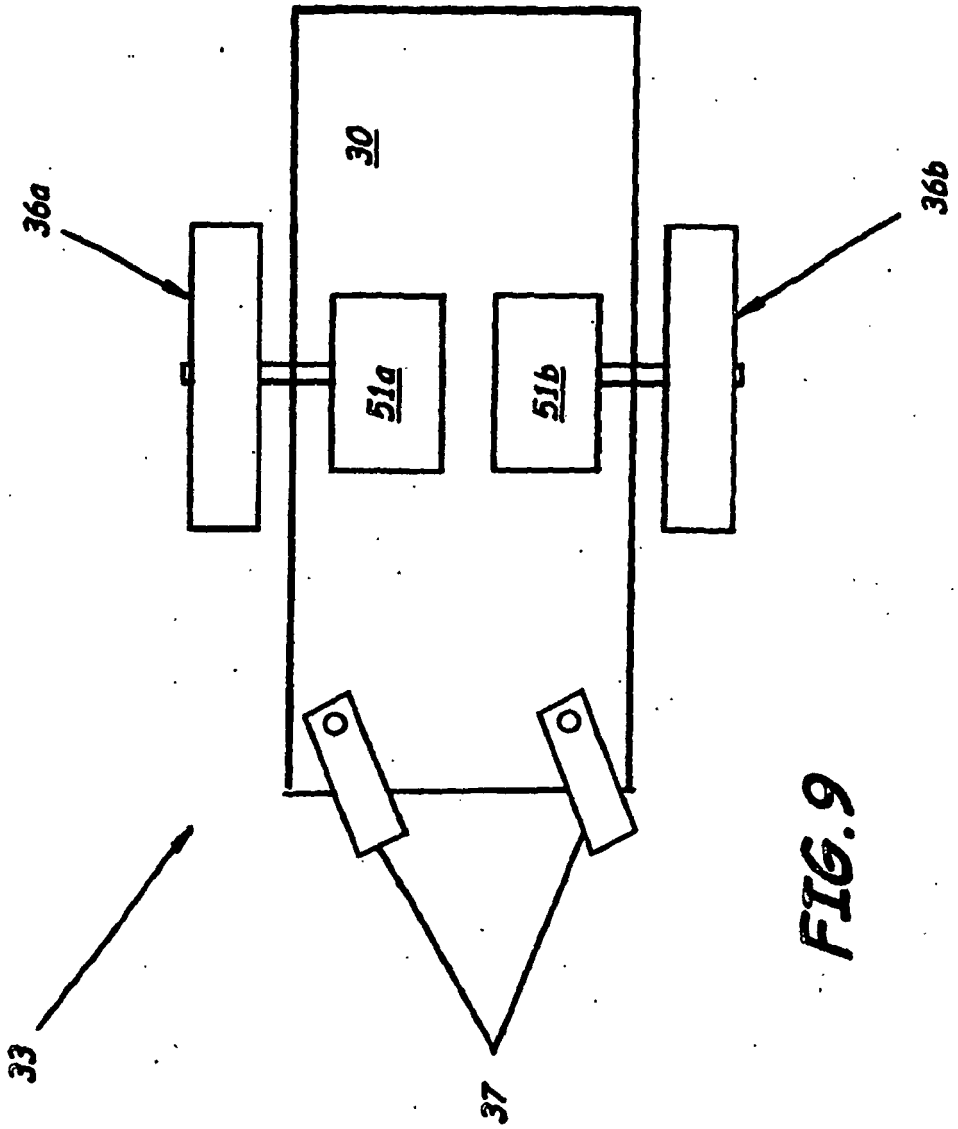
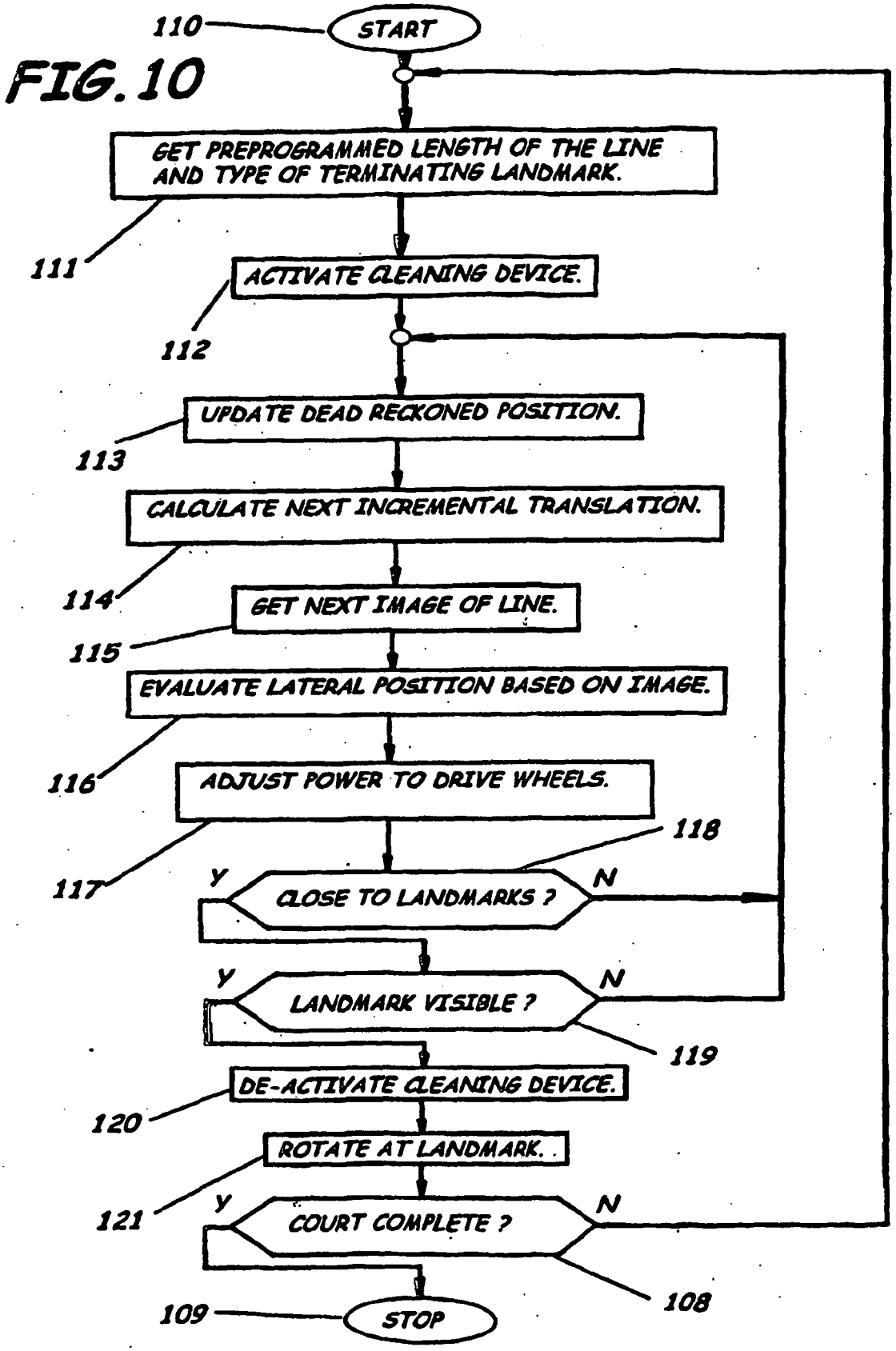


FIG. 9

FIG. 10


110
START
GET PREPROGRAMMED LENGTH OF THE LINE AND TYPE OF TERMINATING LANDMARK.
111
ACTIVATE CLEANING DEVICE.
112
UPDATE DEAD RECKONED POSITION.
113
CALCULATE NEXT INCREMENTAL TRANSLATION.
114
GET NEXT IMAGE OF LINE.
115
EVALUATE LATERAL POSITION BASED ON IMAGE.
116
ADJUST POWER TO DRIVE WHEELS.
117
118
Y
CLOSE TO LANDMARKS ?
N
Y
LANDMARK VISIBLE ?
N
119
DE-ACTIVATE CLEANING DEVICE.
120
ROTATE AT LANDMARK.
121
Y
COURT COMPLETE ?
N
108
109
STOP

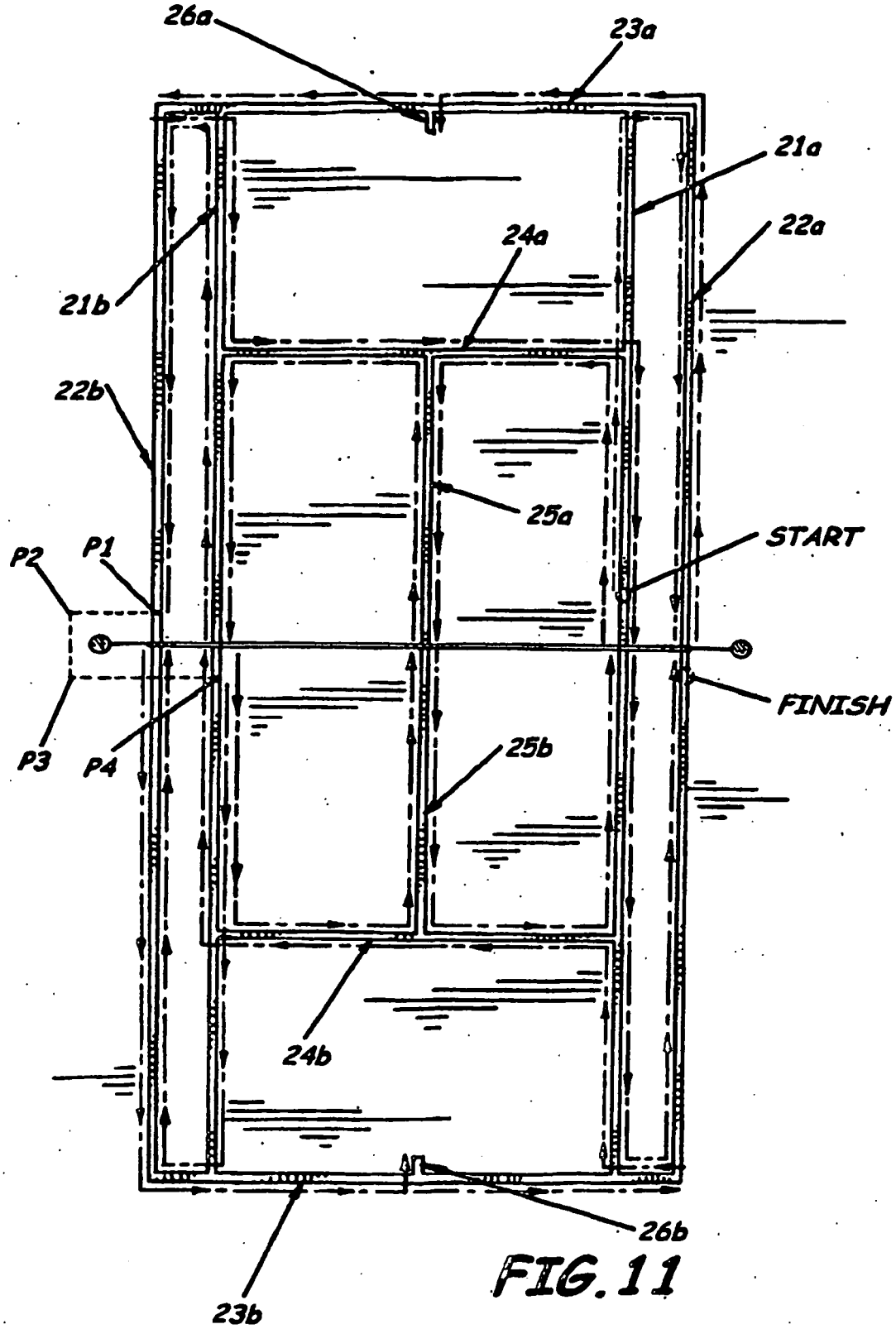

26a
23a
21a
22a
24a
21b
22b
25a
START
P2
P1
P3
P4
FINISH
25b
24b
26b
23b

FIG. 11

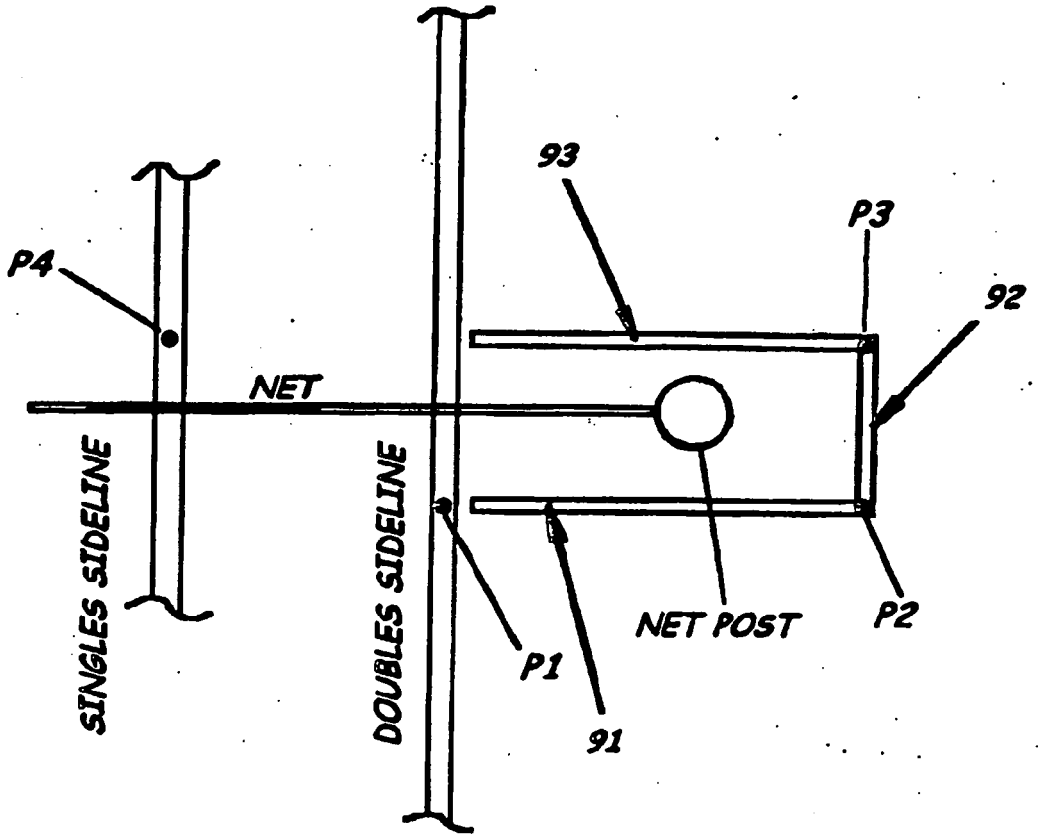

93
P3
92
P4
NET
SINGLES SIDELINE
DOUBLES SIDELINE
NET POST
P2
P1
91

FIG. 12

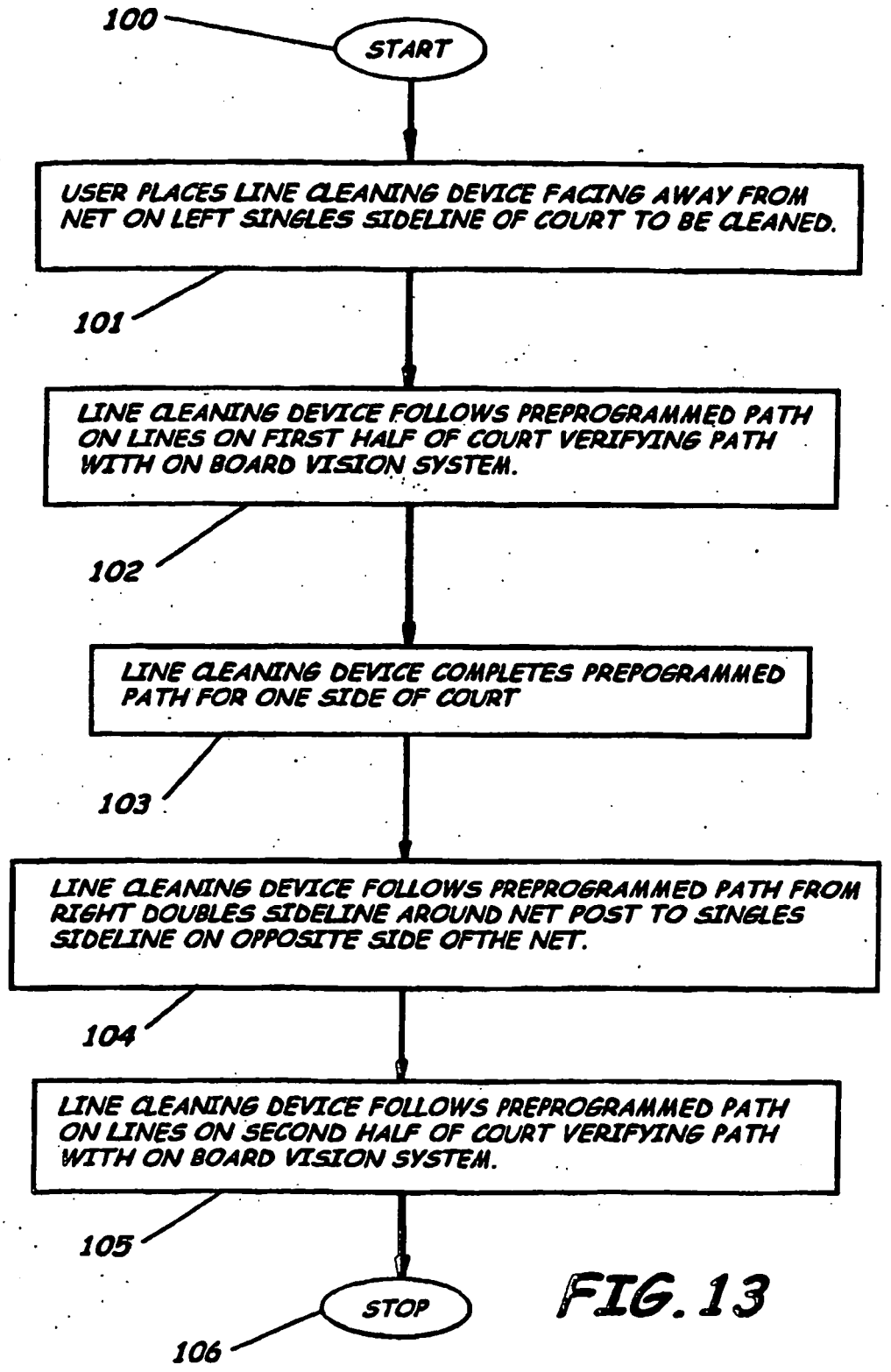

100
START
USER PLACES LINE CLEANING DEVICE FACING AWAY FROM NET ON LEFT SINGLES SIDELINE OF COURT TO BE CLEANED.
101
LINE CLEANING DEVICE FOLLOWS PREPROGRAMMED PATH ON LINES ON FIRST HALF OF COURT VERIFYING PATH WITH ON BOARD VISION SYSTEM.
102
LINE CLEANING DEVICE COMPLETES PREPOGRAMMED PATH FOR ONE SIDE OF COURT
103
LINE CLEANING DEVICE FOLLOWS PREPROGRAMMED PATH FROM RIGHT DOUBLES SIDELINE AROUND NET POST TO SINGLES SIDELINE ON OPPOSITE SIDE OFTHE NET.
104
LINE CLEANING DEVICE FOLLOWS PREPROGRAMMED PATH ON LINES ON SECOND HALF OF COURT VERIFYING PATH WITH ON BOARD VISION SYSTEM.
105
STOP
106

FIG. 13

REFERENCES CITED IN THE DESCRIPTION

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