

AUTONOMOUS DISINFECTION APPARATUS

FIELD

[0001] The present invention generally relates to viral and bacterial disinfection systems, and in particular to an autonomous disinfection apparatus.

BACKGROUND

[0002] The following discussion of the background to the invention is intended to facilitate an understanding of the present invention only. It should be appreciated that the discussion is not an acknowledgement or admission that any of the material referred to was published, known or part of the common general knowledge of the person skilled in the art in any jurisdiction as at the priority date of the invention.

[0003] In the present world, novel virus strains and bacterial infections are becoming more and more common. This brings a huge risk to the general public given the amount interaction that takes place in the community. This involves spaces such as schools, offices, hospitals etc. The most vulnerable area is hospitals where both affected and non-affected patients are treated. This makes it extremely important for the authorities to disinfect the clinics/rooms after each patient is treated. Studies have shown that one of the most common causes of virus transmission happens due to contact surface such as door knobs, arm rests, buttons, remotes etc. UV-C disinfection robots provides a cost-effective solution in preventing such spread of viruses.

[0004] Based on studies, when such viruses/bacteria are exposed to UV-C light, they observe the light energy and causes cell damage and prevents new infections.

Ultraviolet (UV) light is a form of electromagnetic energy produced naturally by the sun. UV light spectrum is just below the visible light and has 4 different spectral categories:

Vacuum UV (100 – 200nm)

UVC (200 – 280nm)

UVB (280 – 315nm)

UVA (315 – 400nm)

[0005] The entire UV spectrum can kill or inactivate many micro-organism species, preventing them from replicating. UV-C energy centred around 254nm provides the most germicidal effect (also known as Ultraviolet Germicidal Irradiation – UVGI). This exposure inactivates microbial organisms such as bacteria and viruses by altering the structure and the molecular bonds of their DNA. The organisms die off leaving no offspring, and the population of the micro-organisms diminishes rapidly.

[0006] Ultraviolet germicidal lamps provide a much more powerful and concentrated effect of UV energy than can be found naturally. Such lamps sanitize air that is passed directly in their path to destroy pathogens that come in contact with the UV rays. Musty, mouldy odour can be eradicated, along with airborne disease threats, including emerging diseases like SARS virus, avian flu and multi-drug resistant bacterial strains (e.g. MRSA) commonly found in hospitals.

[0007] Currently this task is done using an operator who will use a combination of chemicals and UV-C tube towers to disinfect the room. However, due to the nature of UV-C radiation, it cannot be powered on within the proximity of human beings. The radiation as well as the light rays are extremely harmful for the human body. This makes such towers really time consuming to use as the operator needs to monitor the UV tower manually and change the tower's position after each cleaning cycle within the room.

[0008] Current UV-C systems including static towers and robots all utilize a vertical arrangement of the tubes. This method of arrangement purely relies on the intensity of the light to disinfect the area within the optimum range. This is one of the main reasons why the current systems are generally tethered directly to the AC power due to battery limitations. However, in an autonomous robot, getting the most amount of operational duration is necessary.

[0009] The UV-C tubes work most efficiently when the distance between the tube and the surface is closest as well the duration of exposure + intensity. These two variables are inversely proportional. Currently known apparatus generally focus on increased intensity to reduce the exposure time. However, this method is not energy and time efficient.

[0010] An object of the invention is to ameliorate one or more of the above-mentioned difficulties.

SUMMARY

[0011] According to the present disclosure, there is provided an autonomous disinfection apparatus including; an autonomous disinfection apparatus comprising: a support base having an autonomously controllable propulsion system; an elongate housing supported on and extending above the support base; a plurality of UV tube assemblies and at least one articulated UV tube assembly supported at or adjacent an external periphery of the housing, and mounted in a generally vertical position thereon; and an articulation mechanism associated with the or each articulated UV tube assembly for supporting and controlling the position of the associated UV tube assembly between said generally vertical position and a generally horizontal position.

[0012] In some embodiments, the articulation mechanism may further control movement of the associated UV tube assembly between a lower and higher position thereof.

[0013] In some embodiments, the articulation mechanism may move the associated UV tube assembly in a first stage of movement where the UV tube assembly is moved from the generally vertical position to the generally horizontal position, and a second stage of movement where the UV tube assembly is moved from the lower to higher position while held in the generally horizontal position.

[0014] In some embodiments, the articulation system may comprise: a tube holder bracket upon which is mounted a said articulated UV tube assembly; a

sliding rail; a sliding block interconnected to the tube holder bracket and slidably mounted on the sliding rail, an articulation assembly for urging the sliding block for travel along the sliding rail; and a gear arrangement for moving the associated UV tube assembly between the generally vertical and horizontal positions.

[0015] In some embodiments, the actuation assembly may comprise an actuation motor, a lead screw extending from and driven for rotation by the actuation motor, and a flange nut connected to the sliding block.

[0016] In some embodiments, the gear arrangement may comprise a spur gear fixedly mounted on the tube holder bracket, and a rack gear fixedly supported on the sliding rail and engaging the spur gear when the associated UV tube assembly is moved between the generally vertical and horizontal positions.

[0017] In some embodiments, the autonomous disinfection apparatus may comprise an electrical/electronic system comprising, a battery for providing power to the disinfection apparatus, at least one DC to AC inverter for providing AC power to each said tube assembly, a processor for controlling the disinfection apparatus, and motion detection means for detecting objects surrounding the disinfection apparatus.

[0018] In some embodiments, the autonomous disinfection apparatus may further comprise a safety system for shutting off power to the DC to AC inverters and actuation assembly when motion is detected near the disinfection apparatus.

[0019] In some embodiments, the motion detection means may comprise at least one PIR sensor.

[0020] In some embodiments, the autonomous disinfection apparatus may further include objection detection means for controlling movement and preventing collisions with the disinfection apparatus and the articulated tube assembly(s) during movement thereof. The object detection means may comprise at least one LIDAR sensors and at least one depth camera mounted on the housing.

[0021] In some embodiments, the UV tube assemblies may emit UV-C light.

[0022] Other aspects and features will become apparent to those of ordinary skill in the art upon review of the following description of specific embodiments in conjunction with the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] In the figures, which illustrate, by way of example only, embodiments of the present disclosure,

[0024] Figure 1 is a perspective view of an autonomous disinfection apparatus according to the present disclosure;

[0025] Figure 2 is a perspective view of the autonomous disinfection apparatus of Fig. 1 showing articulated UV tube assemblies in a lower horizontal position;

[0026] Figure 3: is a perspective view of the autonomous disinfection apparatus of Fig. 1 showing articulated UV tube assemblies in an upper horizontal position;

[0027] Figure 4 is a partial interior view of a lower portion of the autonomous disinfection apparatus of Fig. 1;

[0028] Figure 5 is a partial side view of an articulation mechanism for the articulated UV tube assemblies;

[0029] Figure 6 is a partial perspective view of the articulation mechanism of Fig. 5;

[0030] Figure 7 is a partial front view of the articulation mechanism of Fig. 5 showing the UV tube assembly in a vertical orientation;

[0031] Figure 8 is a partial front view of the articulation mechanism of Fig. 5 showing the UV tube assembly in an inclined position;

[0032] Figure 9 is a partial front view of the articulation mechanism of Fig. 5 showing the UV tube assembly in a horizontal position;

[0033] Figure 10 is a detailed perspective view of the gear arrangement of the articulation mechanism of Fig. 5;

[0034] Figure 11 is a schematic diagram of the electric/electronic system of the autonomous disinfection apparatus of Fig. 1;

[0035] Figure 12 is a schematic diagram showing the multi-layer safety system of the autonomous disinfection apparatus of Fig. 1;

[0036] Figure 13 is a top view of the of the autonomous disinfection apparatus of Fig. 1 showing the field of view of depth cameras mounted thereon;

[0037] Figure 14 is side perspective view of the autonomous disinfection apparatus of Fig. 1 showing the field of view of LIDAR sensors mounted thereon; and

[0038] Figure 15 is a side perspective view of the autonomous disinfection apparatus of Fig. 1 showing the combined field of views of the depth cameras and LIDAR sensors

DETAILED DESCRIPTION

[0039] Throughout this document, unless otherwise indicated to the contrary, the terms “comprising”, “consisting of”, “having” and the like, are to be construed as non-exhaustive, or in other words, as meaning “including, but not limited to”.

[0040] Furthermore, throughout the specification, unless the context requires otherwise, the word “include” or variations such as “includes” or “including” will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

[0041] Throughout the description, it is to be appreciated that the term ‘processor’ and its plural form include microcontrollers, microprocessors, programmable integrated circuit chips such as application specific integrated circuit chip (ASIC), computer servers, electronic devices, and/or combination thereof capable of processing one or more input electronic signals to produce one or more output electronic signals. The processor includes one or more input modules and one or more output modules for processing of electronic signals.

[0042] Throughout the description, it is to be appreciated that the term ‘server’ and its plural form can include local, distributed servers, and combinations of both local and distributed servers.

[0043] Throughout the description, it is to be appreciated that the term ‘channel’ or ‘channels’ include wired or wireless electronic communication channels. The wireless electronic communication channels may include, but is not limited to, Wi-Fi, Bluetooth, Bluetooth LE, GPRS (General Packet Radio Service), Enhanced Data GSM Evolution (EDGE) etc.

[0044] Unless defined otherwise, all technical and scientific terms used herein have the same meaning as is commonly understood by a skilled person to which the subject matter herein belongs.

[0045] Referring initially to Figs. 1 to 3, there is shown an autonomous disinfection apparatus 1 according to the present disclosure. The apparatus 1 includes a support base 3, within which is provided an autonomously controllable propulsion system (not shown). An elongate housing 5, or ‘tower’, is supported on and extends above the support base 3.

[0046] A series of static UV-C tube assemblies 9 are located around an external periphery 7 of the housing 5. In the embodiment as described, eight static UV-C tube assemblies 9 are spaced around the housing external periphery 7. Each static tube assembly 9 is mounted in a generally vertical position around the housing 7. One or more articulated UV-C tube assemblies 11 are also located at or adjacent the housing external periphery 7. In the described embodiment, two articulated left and right tube assemblies 11 are located on opposing sides of the housing 5. Each articulated UV-C tube assembly 11 is supported by an associated articulation mechanism 15 which will be subsequently described in more detail.

[0047] As shown in Figs. 2 and 3, the associated articulation mechanism 15 of each articulated tube assembly 11 can rotate that tube assembly 11 from a generally vertical position as shown in Fig. 1 to a generally horizontal position as shown in Figs. 2 and 3, or any intermediate angle between these two positions. The articulation mechanism 15 can also control the spacing of the two articulated UV-C tube assemblies 11 from the support housing 3, between a lower position as shown

in Fig. 2 and a higher position as shown in Fig. 3. This allows the UV-C tube assembly position to be best configured to provide the most efficient disinfection of surfaces such as beds, chairs, and tabletops within the environment being disinfected.

[0048] The height of the apparatus 1 requires the centre of gravity of the apparatus to be as low as possible to facilitate stability of the apparatus 1 during movement. Therefore, heavier components can be located within the lower portion 6 of the housing 5. As shown in Fig. 4, these components can include a battery 33 providing the power supply for the apparatus 1, DC to AC inverters 35 used to provide AC power to the static and articulated UV-C tube assemblies 9,11, ballasts 37 for each tube assembly 9,11, and traction motor drivers 31 for the traction motors (not shown) of the autonomously controllable propulsion system within the support base 3.

[0049] Figs. 5 to 10 show in more detail the various components of the articulation mechanism 15 according to the present disclosure. The mechanism 15 includes a sliding block 26 that is slidably mounted on a sliding rail 16. The sliding rail 16 extends in a generally vertical position within the interior of the housing 5. The sliding block 26 can be moved along the sliding rail 16 by means of an actuation assembly 18 including an actuation motor 23, a lead screw 25 extending from and driven for rotation by the motor 23, and a flange nut 27 connected to the sliding block 26. The lead screw 25 extends through the flange nut 27, and rotation of the lead screw 25 in opposing directions results in movement of the sliding block 26, which is connected to the flange nut 27, in an upward or downward direction along the sliding rail 16.

[0050] The associated UV-C tube assembly 11 is mounted to the articulation mechanism 15 via a tube holder bracket 17. The tube holder bracket 17 is interconnected to the sliding block 26 via a gear arrangement 19 including a spur gear 20 rotatably mounted on the sliding block 26 via a bearing, such as a roller bearing, housed within the spur gear 20. That spur gear 20 is fixedly secured to the tube holder bracket 17. The gear arrangement 19 further includes a gear block 21 fixedly secured to the sliding rail 16. The gear block 21 supports a rack gear 22 that is engageable with the spur gear 20.

[0051] In the initial or 'home' position of the articulated tube assembly 11, the tube assembly 11 is held in a generally vertical direction as shown in Fig. 7. The spur gear 20 and rack gear 22 are initially engaged when in this home position. When the sliding block 26 is actuated for movement in an upwards generally vertical direction by the actuation assembly 18 in a first stage of movement, the engagement of the spur gear 20 with the fixed rack gear 21 results in rotation of the spur gear and therefore the tube holder bracket 17 fixedly secured to the spur gear 20. This initially results in the tube holder bracket 17, and the tube assembly 11 mounted on the bracket 17, rotating from the generally vertical direction to an inclined position as shown in Fig. 8 before reaching a generally horizontal position as shown in Fig. 9. When the tube assembly 11 reaches that generally horizontal position, the spur gear 20 can disengage with the fixed rack gear 22 and can continue to move in an upward direction together with the sliding block 26 and tube holder bracket 17 in a second stage of movement. The tube assembly 11 will remain in the generally horizontal position during this second stage.

[0052] The autonomous disinfection apparatus 1 according to the present disclosure has an electrical/electronic system 100 for powering and controlling the operation of the apparatus 1 as shown in Fig. 11. This system 100 is powered by a battery, for example having a rating of 24V and 100Ah. This battery 101 can directly connected, via a power distribution board 103, to the left and right actuation motors 23, left and right traction motors 103 of the autonomous controllable propulsion drive, a processor in the form of an industrial PC 113 and other DC powered components of the apparatus 1. Two DC-AC inverters 105, 107, that may preferably be rated at 300W and 1000W respectively, are also connected to the battery 101 via the power distribution board 103. These DC-AC inverters 105,107 respectively provide AC power to the static tube assemblies 9, and articulated tube assemblies 11 via individual ballasts 37 for regulating the current to each tube assembly 9,11.

[0053] It is envisaged that the autonomous disinfection apparatus 1 may include safety sensors to enable the apparatus to operate in an environment where no human is present and subject to direct exposure. This requires the integration of motion detection sensors together with the industrial PC 113. The apparatus may

also utilize a depth camera to constantly scan 360 degrees around the apparatus for obstacles as well any movements. These sensors provide a multi-layered safety net to help to ensure the UV tube assemblies 9,11 will cut-off immediately once any movement is detected

[0054] The set-up of the multi-layer safety system of the of the autonomous disinfection apparatus 1 is shown in more detail in Fig. 12. This safety layer can provide three layers of safety by splitting the power provided by the battery 101, which may have a 24V rating, into a first section powering the industrial PC 113 and sensors 115, and a second section powering the motors 23,111 and the invertors 105,107 powering the UV-C tube assemblies 9,11. In the first layer of safety, the actuation of emergency or 'E-Stop' button 117 results in the power being cut off to the second section, so that only the industrial PC 113 and sensors 115 which do not move and do not possess any danger, remain powered. In the second layer of safety, the industrial PC 113 can send a signal to a relay 119 to thereby cut off the power to the DC to AC inverters 105,107. This second layer can also function as a digital ON/OFF switch for the UV-C tube assemblies 9,11. In the third layer of safety, motion sensors 121, which may for example be PIR sensors, can use infrared thermal imaging technology to detect for the presence of any movement in the operating environment. The UV-C tube assemblies 9,11 can only be triggered in an environment without the presence of human beings. These motions sensors 121 are triggered upon a movement being detected, and the power to the DC to AC inverters 105,107 can be cut-off, resulting the UV-C tube assemblies 9,11 being turning Off.

[0055] The autonomous disinfection apparatus 1 may also be provided with an obstacle avoidance system which is a requirement in view of the autonomous operation of the apparatus 1. Fig. 13 shows the apparatus 1 provided with three depth cameras 123 spaced around a front periphery of the housing 5. The combined field of view 125 of the three depth cameras 123 as shown in Fig. 13 provide a 180-degree view towards the front of the apparatus 1. The field of view of each depth camera 123 can overlap to thereby minimise any blind spots in the combined field of view. It is also envisaged that other numbers of depth cameras, including only one, can be used for this purpose.

[0056] The autonomous disinfection apparatus 1 may also be provided with sensors 115, such as LIDAR sensors, that may be used in conjunction with the depth cameras 123, to provide the object detection for the apparatus 1. Fig. 14 shows the apparatus 1 being provide with two LIDAR sensors 115a AND 115b, with one LIDAR sensor 115a being downwardly angled to provide a virtual curtain 127. The other LIDAR sensor 115b may be angled horizontally along the plane of the floor surface to provide a horizontal curtain 129. During autonomous operation of the apparatus 1, and in particular during articulation of the articulated tube assemblies 11, both the depth cameras 123 and LIDAR sensors 115a,115b can act together to ensure that there are no objects in the path of actuation of the articulated tube assemblies 11 as shown in Fig. 15.

[0057] The autonomous disinfection apparatus according to the present disclosure may provide autonomous navigation with the most optimized path: The autonomous disinfection apparatus may utilize lidar and depth camera data to plan the path within the environment to ensure maximum intensity of UV-C exposure within the shortest time possible. The user can set the definite cleaning points to have a mandatory cleaning procedure.

[0058] It is also envisaged that a remote processor such as a smart phone providing amobile app interface to provide a channel that may also control the autonomous disinfection apparatus remotely as well as trigger the autonomous navigation. The app can also be used to remotely adjust the UV-C tube assembly configurations.

[0059] The autonomous disinfection apparatus can configure the angle of the UV-c tube to have a more efficient disinfection of surfaces such as beds, chairs and table tops. It is envisaged that the articulated tube assemblies 11 may have a collision avoidance system to ensure high safety standards within the hospital environment.

[0060] Currently the autonomous disinfection apparatus may be equipped with Lidar, Depth Camera and obstacle detection sensors. The autonomous disinfection apparatus may therefore be used in remote controlled mode. It is however also envisaged that the software system of the control system be upgraded to allow

autonomous movement within an environment without the need of pre-mapping. This will enable the user to determine the points in the room/area to disinfect, and the autonomous disinfection apparatus will find the most optimized path such that it can provide maximum UV-C exposure in the least amount of time.

[0061] The autonomous disinfection apparatus according to the present disclosure, can navigate within, for example, a hospital environment without human intervention reducing the time required to disinfect that environment. As the autonomous disinfection apparatus may be powered using a battery, it does not need to be tethered to any AC power supply. Furthermore, the articulated UV-C tube assemblies may be positioned at different orientations and heights to provide the best UV-C exposure to objects and surfaces within that environment.

[0062] It should be appreciated by the person skilled in the art that the above invention is not limited to the embodiment described. It is appreciable that modifications and improvements may be made without departing from the scope of the present invention.

[0063] It should be further appreciated by the person skilled in the art that one or more of the above modifications or improvements, not being mutually exclusive, may be further combined to form yet further embodiments of the present invention.

CLAIMS

1. An autonomous disinfection apparatus comprising:
a support base having an autonomously controllable propulsion system;
an elongate housing supported on and extending above the support base;
a plurality of UV tube assemblies and at least one articulated UV tube assembly supported at or adjacent an external periphery of the housing, and mounted in a generally vertical position thereon; and
an articulation mechanism associated with the or each articulated UV tube assembly for supporting and controlling the position of the associated UV tube assembly between said generally vertical position and a generally horizontal position.
2. An autonomous disinfection apparatus according to claim 1, wherein the articulation mechanism further controls movement of the associated UV tube assembly between a lower and higher position thereof.
3. An autonomous disinfection apparatus according to claim 2, wherein the articulation mechanism moves the associated UV tube assembly in a first stage of movement where the UV tube assembly is moved from the generally vertical position to the generally horizontal position, and a second stage of movement where the UV tube assembly is moved from the lower to higher position while held in the generally horizontal position.
4. An autonomous disinfection apparatus according to any one of the preceding claims, wherein the articulation system comprises: a tube holder bracket upon which is mounted a said articulated UV tube assembly; a sliding rail; a sliding block interconnected to the tube holder bracket and slidably mounted on the sliding rail, an articulation assembly for urging the sliding block for travel along the sliding rail; and a gear arrangement for moving the associated UV tube assembly between the generally vertical and horizontal positions.

5. An autonomous disinfection apparatus according to claim 4, wherein the actuation assembly comprises an actuation motor, a lead screw extending from and driven for rotation by the actuation motor, and a flange nut connected to the sliding block.
6. An autonomous disinfection apparatus according to claim 5, wherein the gear arrangement comprises a spur gear fixedly mounted on the tube holder bracket, and a rack gear fixedly supported on the sliding rail and engaging the spur gear when the associated UV tube assembly is moved between the generally vertical and horizontal positions.
7. An autonomous disinfection apparatus according to any one of claims 4 to 6, comprising an electrical/electronic system comprising, a battery for providing power to the disinfection apparatus, at least one DC to AC inverter for providing AC power to each said tube assembly, a processor for controlling the disinfection apparatus, and motion detection means for detecting objects surrounding the disinfection apparatus.
8. An autonomous disinfection apparatus according to claim 7 further comprising a safety system for shutting off power to the DC to AC inverters and actuation assembly when motion is detected near the disinfection apparatus.
9. An autonomous disinfection apparatus according to claim 7 or 8, wherein the motion detection means comprises at least one PIR sensor.
10. An autonomous disinfection apparatus according to any one of the preceding claims further including objection detection means for controlling movement and preventing collisions with the disinfection apparatus and the articulated tube assembly(s) during movement thereof.
11. An autonomous disinfection apparatus according to claim 10, wherein the object detection means comprises at least one LIDAR sensors and at least one depth camera mounted on the housing.

12. An autonomous disinfection apparatus according to any one of the preceding claims, wherein the UV tube assemblies emit UV-C light.