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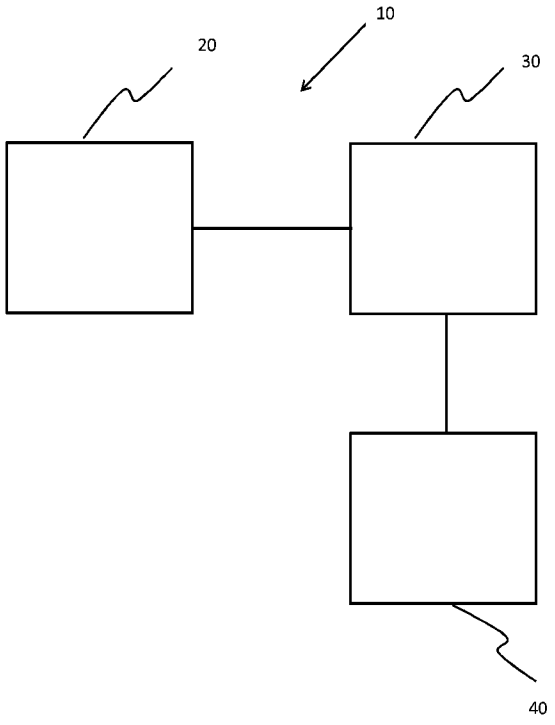

Fig. 1

(57) Abrégé/Abstract:
The present invention relates to an apparatus for weed control. It is described to provide (210) a processing unit with at least one image of an environment. The processing unit analyses (220) the at least one image to determine at least one vegetation control technology from a plurality of vegetation control technologies to be used for weed control for at least a first part of the environment. An output unit outputs (230) information that is useable to activate the at least one vegetation control technology.

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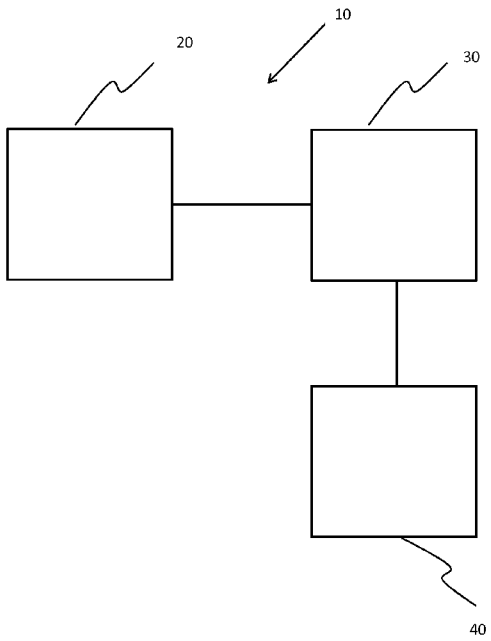

Fig. 1

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APPARATUS FOR WEED CONTROL

FIELD OF THE INVENTION

The present invention relates to an apparatus for weed control, to a system for weed control, to a method for weed control, as well as to a computer program element and a computer readable medium.

BACKGROUND OF THE INVENTION

The general background of this invention is weed control. Certain industrial areas and areas around railway tracks need to have the vegetation controlled. For railways, such control improves visibility from the perspective of people on the train such as the driver and improves visibility from the perspective of people working on the tracks. Such control can lead to improved safety. Additionally, vegetation can disrupt or damage tracks and associated signaling and communication lines. Control of the vegetation is then required to mitigate this. Vegetation control, also called weed control, can be very time and resource consuming, especially if carried out manually. A weed sprayer train, with a herbicide contained in chemical tanks on the train can be sprayed onto the track and surrounding area to control the vegetation. However, such weed control can be expensive, and the general public increasingly wishes to see a reduction in environmental impact.

SUMMARY OF THE INVENTION

It would be advantageous to have improved apparatus for weed control.

The object of the present invention is solved with the subject matter of the independent claims, wherein further embodiments are incorporated in the dependent claims. It should be noted that the following described aspects and examples of the invention apply also for the apparatus for weed control, the system for weed control, the method for weed control, and for the computer program element and the computer readable medium.

According to a first aspect, there is provided an apparatus for weed control, comprising:

- an input unit;
- a processing unit; and
- an output unit.

The input unit is configured to provide the processing unit with at least one image of an environment. The processing unit is configured to analyse the at least one image to determine at least one vegetation control technology from a plurality of vegetation control technologies to be used for weed control for at least a first part of the environment. The output unit is configured to output information useable to activate the at

least one vegetation control technology. In other words, an image or images of an environment have been acquired. There are a number of possible vegetation control technologies that can be used for weed control. The apparatus then analyses the image or images to determine which one or ones of the available vegetation control technologies should be used to control weeds at a specific location or locations of the environment.

In this way, the most appropriate vegetation control technology can be used for different areas of the environment. Also, at different areas of the environment, different technologies can be used, where each technology is the most appropriate for each different area.

In this manner, herbicide based technologies, for example that can be applied in a spray form, can be used only where they are the most appropriate technology for a particular area or areas of the environment. This also means, that non-herbicide technologies can be utilized at other areas of the environment. Thus, not only is the overall control of weeds improved because the most appropriate technology is used for each area, the use of herbicides and particularly of the most aggressive herbicides is reduced.

In an example, analysis of the at least one image to determine at least one vegetation control technology comprises a determination of at least one location of vegetation in the at least first part of the environment. The processing unit is configured then to determine the at least one vegetation control technology to be used at that at least one location.

In other words, image processing can be used in order to determine the areas of vegetation in the acquired imagery, from which the most appropriate technology to be used for weed control of that vegetation area can be selected. Also, the vegetation control technologies can be applied only at the location of vegetation, where the most appropriate vegetation control technology can be used for each location of vegetation.

In this manner, the most appropriate vegetation control technology can be selected for different vegetation areas, where small areas of vegetation can be controlled via different means to large areas of vegetation for example.

In an example, the at least one image was acquired by at least one camera. The input unit is configured to provide the processing unit with at least one location associated with the at least one camera when the at least one image was acquired.

The location can be a geographical location, with respect to a precise location on the ground, or can be a location on the ground that is referenced to a position of at least one vegetation control technology. In other words, an absolute geographical location can be utilized or a location on the ground that need not be known in absolute terms, but that is referenced to a location of a weed control technology.

Thus, by correlating an image with the location where it was acquired, this being an absolute geographical location or a location on the ground that is known with respect to the position of a vegetation control technology, the vegetation control technology can be accurately applied to that location.

In an example, analysis of the at least one image to determine the at least one vegetation control technology comprises a determination of at least one type of weed. In other words, the appropriate vegetation control technology being selected can account for the type or types of weeds to be controlled. In an example, the processing unit is configured to determine at least one location of the at least one type of weed. In other words, image processing can be used to determine a type of weed and its location. The location can be the location within the imagery. The location can be an actual geographical location. The location can be within the imagery and be able to be referenced a position of one or more vegetation control technologies. In this manner, by determining a location of a particular type of weed, the most optimum vegetation control technology can be applied to that specific location, with this also applying to different weeds at different locations that required different vegetation control technologies to be applied.

In an example, analysis of the at least one image to determine the at least one vegetation control technology comprises a determination of a first type of weed in the at least first part of the environment and a determination of a second type of weed in at least a second part of the environment.

Thus the most appropriate vegetation control technology can be determined on the basis of different weed types in an environment. In an example, the processing unit is configured to analyse the at least one image to determine a first vegetation control technology to be used for weed control for the first type of weed in the at least the first part of the environment. The processing unit is configured also to analyse the at least one image to determine a

second vegetation control technology to be used for weed control for the second type of weed in at least a second part of the environment.

In other words, the most appropriate vegetation control technology can be selected depending upon the specific type of types of weed to be found in parts of an environment, thereby enabling specific vegetation control technologies to be applied only at the locations where those specific weeds are to be found. In an example, the processing unit is configured to analyse the at least one image to determine a first vegetation control technology from the plurality of vegetation control technologies to be used for weed control for at least the first part of the environment. The processing unit is configured also to analyse the at least one image to determine a second vegetation control technology from the plurality of vegetation control technologies to be used for weed control for at least a second part of the environment.

In other words, a first technology can be selected on the basis of image analysis for weed control at first locations of an environment, and a different vegetation control technology can be selected for weed control at different locations on the basis of image analysis.
In this manner, the most appropriate vegetation control technology can be selected for certain parts of the environment, with for example one weed control technology being used for some weeds and a different vegetation control technology being used for different weeds, and/or one vegetation control technology can be used for certain types of weeds in a first part of an environment, and a different vegetation control technology be used for the same weeds in a different part of the environment. For example, the selected vegetation control technology can account for the ground terrain, taking into account for example if the terrain is dry, sandy, marshy, wet, or an area of special environmental importance (protected area) and the most appropriate vegetation control technology selected to account for these terrain types for the same types (or different types) of weeds.

In another example, the most appropriate vegetation control technology can be determined on the basis of a growth stage or a development stage of a weed species. According to one permissive embodiment, the development stage may be defined by a BBCH (the international accepted code from Biologische Bundesanstalt, Bundessortenamt und Chemische Industrie in Germany).

In another example, the most appropriate vegetation control technology can be determined on the basis of an amount of weed in an environment.

Additionally, this means that chemically aggressive weed control means can be kept to a minimum.

In an example, analysis of the at least one image comprises utilisation of a machine learning algorithm.

In the above discussion, and that that follows, vegetation control technology can also be termed weed control technology and vice versa.

According to a second aspect, there is provided a system for weed control, comprising:

- at least one camera;
- an apparatus for weed control according to the first aspect; and
- at least one vegetation control technology.

The at least one camera is configured to acquire the at least one image of the environment. The at least one vegetation control technology is mounted on a vehicle. The apparatus is configured to activate the at least one vegetation control technology for the at least first part of the environment.

In this way, a vehicle can move around an environment and control weeds within that environment using different vegetation control technologies, where specific vegetation control technologies are determined on the basis of imagery of that environment. In this way, imagery can be acquired by one platform, for example one or more drones that fly over an environment. That information is sent to an apparatus, that could be in an office. The apparatus determines what vegetation control technology should be used where, within the environment. This information, can be provided in a weed control map, that is provided to a vehicle that moves around that environment, and at specific parts of the environment activates the required vegetation control technology.

In an example, the apparatus is mounted on the vehicle. In an example, the at least one camera is mounted on the vehicle.

According to a third aspect, there is provided a method for weed control, comprising:

(a) providing a processing unit with at least one image of an environment;

(c) analysing by the processing unit the at least one image to determine at least one vegetation control technology from a plurality of vegetation control technologies to be used for weed control for at least a first part of the environment; and

(e) outputting information by an output unit that is useable to activate the at least one vegetation control technology.

In an example, step c) comprises step determining (240) at least one location of vegetation in the at least first part of the environment; and wherein the method comprises step d) determining (250) by the processing unit the at least one vegetation control technology to be used at that at least one location.

In an example, in step a) the at least one image was acquired by at least one camera; and wherein the method comprises step b) providing (260) the processing unit with at least one location associated with the at least one camera when the at least one image was acquired.

According to another aspect, there is provided a computer program element for controlling an apparatus according to the apparatus of the first aspect and/or system according to the second aspect, which when executed by a processor is configured to carry out the method of the third aspect. Advantageously, the benefits provided by any of the above aspects equally apply to all of the other aspects and vice versa.

The above aspects and examples will become apparent from and be elucidated with reference to the embodiments described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

Exemplary embodiments will be described in the following with reference to the following drawings:

Fig. 1 shows a schematic set up of an example of an apparatus for weed control;

Fig. 2 shows a schematic set up of an example of a system for weed control;

Fig. 3 shows a method for weed control;

Fig. 4 shows a schematic set up of an example of a system for weed control;

Fig. 5 shows a schematic set up of an example of a system for weed control;

Fig. 6 shows a schematic set up of an example of a part of a system for weed control;

Fig. 7 shows a schematic set up of an example of a part of a system for weed control;

Fig. 8 shows a schematic set up of an example of a part of a system for weed control;

Fig. 9 shows a schematic set up of more detail of a section of the part of the system for weed control shown in Fig. 7; and

Fig. 10 shows a schematic representation of a railway track and surrounding area.

DETAILED DESCRIPTION OF EMBODIMENTS

Fig. 1 shows an example of an apparatus 10 for weed control. The apparatus 10 comprises an input unit 20, a processing unit 30 and an output unit 40. The input unit 20 is configured to provide the processing unit 30 with at least one image of an environment. The processing unit 30 is configured to analyse the at least one image to determine at least one vegetation control technology from a plurality of vegetation control technologies to be used for weed control for at least a first part of the environment. The output unit 40 is configured to output information useable to activate the at least one vegetation control technology. The at least one vegetation control technology is activated at the at least first part of the environment.

In an example, the apparatus operates in real-time, where images are acquired and immediately processed and the determined vegetation control technology is immediately used to control weeds. Thus, for example a vehicle can acquire imagery of its environment and process that imagery to determine which vegetation control technology carried by the vehicle should be used for particular parts of its environment.

In an example, the apparatus is operated in quasi real time, where images are acquired of an environment and immediately processed to determine which vegetation control technology should be used to control weeds at particular areas of that environment. That information can later be used by an appropriate system (or systems) that travel(s) within the environment and applies the appropriate vegetation control technology to particular parts of that environment. Thus for example, a first vehicle, such as a car, train, lorry or unmanned aerial vehicle (UAV) or drone equipped with one or more cameras can travel within an environment and acquire imagery. This imagery can be immediately processed to determine a “weed map”, detailing where within the environment specific vegetation

control technologies should be used. Later, a vehicle equipped with a number of different vegetation control technologies can travel within the environment and apply the specific determined weed control technology to different specific areas of the environment. In another example, a number of different vehicles each equipped with a single vegetation control technology travel within the environment and use their specific vegetation control technology only to those specific areas of the environment, where it has been determined that that vegetation control technology should be used.

In an example, the apparatus is operating in an offline mode. Thus, imagery that has previously been acquired is provided later to the apparatus. The apparatus then determines where specific vegetation control technologies should be used within an area, and in effect generates a weed map. The weed map is then used later by one or more vehicles that then travel within the area and apply specific vegetation control technologies to specific parts of the environment.

In an example, the output unit outputs a signal that is directly useable to activate a vegetation control technology.

According to an example, analysis of the at least one image to determine at least one vegetation control technology comprises a determination of at least one location of vegetation in the at least first part of the environment. The processing unit is configured then to determine the at least one vegetation control technology to be used at that at least one location.

According to an example, the at least one image was acquired by at least one camera. The input unit is configured then to provide the processing unit with at least one location associated with the at least one camera when the at least one image was acquired.
In an example, the location is an absolute geographical location.

In an example, the location is a location that is determined with reference to the position of at least one vegetation control technology. In other words, an image can be determined to be associated with a specific location on the ground, without knowing its precise geographical position, but by knowing the position of the at least one vegetation control technology with respect to that location at the time the image was acquired, the vegetation

control technology can then be applied at a later time at that location by moving it to that location.

In an example, a GPS unit is used to determine, and/or is used in determining, the location of the at least one camera when specific images were acquired.

In an example, an inertial navigation unit is used alone, or in combination with a GPS unit, to determine the location of the at least one camera when specific images were acquired. Thus for example, the inertial navigation unit, comprising for example one or more laser gyroscopes, is calibrated or zeroed at a known location and as it moves with the at least one camera the movement away from that known location in x, y, and z coordinates can be determined, from which the location of the at least one camera when images were acquired can be determined.

In an example, image processing of acquired imagery is used alone, or in combination with a GPS unit, or in combination with a GPS unit and inertial navigation unit, to determine the location of the at least one camera when specific images were acquired. Thus visual markers can be used alone, or in combination to determine the location of the camera.
According to an example, analysis of the at least one image to determine the at least one vegetation control technology comprises a determination of at least one type of weed.
According to an example, the processing unit is configured to determine at least one location of the at least one type of weed.

According to an example, analysis of the at least one image to determine the at least one vegetation control technology comprises a determination of a first type of weed in the at least first part of the environment and a determination of a second type of weed in at least a second part of the environment.

According to an example, the processing unit is configured to analyse the at least one image to determine a first vegetation control technology to be used for weed control for the first type of weed in the at least the first part of the environment. The processing unit is configured also to analyse the at least one image to determine a second vegetation control technology to be used for weed control for the second type of weed in at least a second part of the environment.

According to an example, the processing unit is configured to analyse the at least one image to determine a first vegetation control technology from the plurality of vegetation control technologies to be used for weed control for at least the first part of the environment. The processing unit is configured also to analyse the at least one image to determine a second vegetation control technology from the plurality of vegetation control technologies to be used for weed control for at least a second part of the environment.

In an example, the at least second part of the environment is different to the at least first part of the environment.

Thus, different weeds can be determined to be in different parts of an environment to enable the most appropriate vegetation control technology to be determined for those areas.

In an example, the at least second part of the environment is at least partially bounded by the at least first part of the environment.

In other words, an area of an environment is found within another area of an environment. One vegetation control technology can be then be used for a large area and for a smaller area to be found within that area, another vegetation control technology can be used.

In an example, the at least second part of the environment is at least one subset of the at least first part of the environment.

Thus a smaller area of for example a specific type of weed can be found within a larger area of a weed. For example, one or more dandelions can be located within a region of grass. Then, a first vegetation control technology can be used across the whole grass area, including where the dandelions are to be located. This vegetation control technology can be selected as that appropriate to control grass, and need not be the most aggressive vegetation control technology available. However, for the subset of that grass area, where harder to kill weeds such as dandelions are to be found, then a more aggressive vegetation control technology can be used, such as chemical spray at that specific location. In this way, the amount of chemical spray can be minimised.

According to an example, analysis of the at least one image comprises utilisation of a machine learning algorithm.

In an example, the machine learning algorithm comprises a decision tree algorithm.

In an example, the machine learning algorithm comprises an artificial neural network.

In an example, the machine learning algorithm has been taught on the basis of a plurality of images. In an example, the machine learning algorithm has been taught on the basis of a plurality of images containing imagery of at least one type of weed. In an example, the machine learning algorithm has been taught on the basis of a plurality of images containing imagery of a plurality of weeds.

In an example, the at least one vegetation control technology comprises one or more of the following: one or more chemicals; chemical spray; chemical liquid; chemical solid; high pressure water; high temperature water; water at high pressure and temperature; steam; electrical power; electrical induction; electrical current flow; High Voltage power; electromagnetic radiation; x-ray radiation; ultraviolet radiation; visible radiation; microwave radiation; pulsed laser radiation; flame system.

Fig. 2 shows an example of a system 100 for weed control. The system 100 comprises at least one camera 110 and an apparatus 10 for weed control as described above for any of the examples associated with Fig. 1. The system 100 also comprises at least one vegetation control technology 120. The at least one camera 110 is configured to acquire the at least one image of the environment. The at least one vegetation control technology 120 is mounted on a vehicle 130. The apparatus 10 is configured to activate the at least one vegetation control technology 120 for the at least first part of the environment.
In an example, the apparatus 10 is mounted on the vehicle 130. In an example, the at least one camera 110 is mounted on the vehicle 130.

In an example, the vehicle is a train, or train wagon, or lorry or truck or Unimog.
In an example, the input unit is configured to provide the processing unit with at least one geographical location associated with the at least one camera when the at least one image was acquired.

In an example, the apparatus is configured to activate the at least one vegetation control technology on the basis of the at least one geographical location associated with the at least one camera when the at least one image was acquired and a spatial relationship between the at least one camera and the at least one vegetation control technology. In this manner, by knowing where the image has been acquired by a camera mounted on a vehicle and also knowing where a vegetation control technology is mounted on the vehicle with respect to the camera, the forward movement of the vehicle can be taken into account in order to

activate that vegetation control technology at the same location where the image was acquired, and indeed within that imaged area.

In an example, the apparatus is configured to activate a first vegetation control technology before activation of a second vegetation control technology, or activate the first vegetation control technology after activation of the second vegetation control technology.

In an example, the first vegetation control technology is mounted in front of the second vegetation control technology with respect to a direction of travel of the vehicle, or the first vegetation control technology is mounted behind the second vegetation control technology with respect to the direction of travel of the vehicle.

Fig. 3 shows a method 200 for weed control in its basic steps. The method 200 comprises:
in a providing step 210, also referred to as step (a), providing 210 a processing unit 30 with at least one image of an environment;
in an analyzing step 220, also referred to as step (c), analysing by the processing unit the at least one image to determine at least one vegetation control technology from a plurality of vegetation control technologies to be used for weed control for at least a first part of the environment; and
in an outputting step 230, also referred to as step (e), outputting information by an output unit 40 that is useable to activate the at least one vegetation control technology.

In an example, the at least one image of the environment is provided from an input unit 20 to the processing unit.

According to an example, step c) comprises the step of determining 240 at least one location of vegetation in the at least first part of the environment. The method then comprises step d) determining 250 by the processing unit the at least one vegetation control technology to be used at that at least one location.

According to an example, in step a) the at least one image was acquired by at least one camera, and the method comprises step b) providing 260 the processing unit with at least one location associated with the at least one camera when the at least one image was acquired.

In an example, step c) comprises determining 270 at least one type of weed.

In an example, c) comprises determining 280 at least one location of the at least one type of weed.

In an example, step c) comprises determining 290 a first type of weed in the at least first part of the environment and determining 300 of a second type of weed in at least a second part of the environment.

In an example, step c) comprises determining 310 a first vegetation control technology to be used for weed control for the first type of weed in the at least the first part of the environment, and determining 320 a second vegetation control technology to be used for weed control for the second type of weed in at least a second part of the environment.

In an example, step c) comprises determining 330 a first vegetation control technology to be used for weed control for at least the first part of the environment, and determining 340 a second vegetation control technology to be used for weed control for at least a second part of the environment.

In an example, the at least second part of the environment is different to the at least first part of the environment.

In an example, the at least second part of the environment is at least partially bounded by the at least first part of the environment.

In an example, the at least second part of the environment is at least one subset of the at least first part of the environment.

In an example, step c) comprises utilising 350 a machine learning algorithm.

In an example, the method comprises using a vehicle, and wherein the method comprises acquiring by at least one camera the at least one image of the environment; and activating the at least one vegetation control technology, that is mounted on the vehicle, for the at least first part of the environment.

In an example, the method comprises mounting the processing unit, the output unit, and the at least one camera on the vehicle.

In an example, the method comprises activating a first vegetation control technology before activating a second vegetation control technology, or activating the first vegetation control technology after activating the second vegetation control technology.

The apparatus, system and method for weed control are now described in more detail in conjunction with Figs. 4-10, which relate to weed control in the environment of a railway track, with the weed control technologies being mounted on parts of the train.

Fig. 4 shows an example of a system 100 for weed control. Several drones have cameras 110. The drones fly along a railway track. The cameras acquire imagery of the environment of the railway track, with this being the ground between the track and the ground to the sides of the track. The environment being imaged is that that is required to have weeds controlled. There need not be several drones, and one drone with one camera 110 can acquire the necessary imagery. Indeed, the imagery could have been acquired by a camera 110 or cameras 110 that were hand held by personnel visiting the railway track environment, by a plane, or by a train that has run along the railway track for example. The imagery acquired by the cameras 110 is at a resolution that enables vegetation to be identified as vegetation and indeed can be at resolution that enables one type of weed to be differentiated from another type of weed. The acquired imagery can be colour imagery but need not be. The imagery acquired by the drones is transmitted to an apparatus 10. The imagery can be transmitted to the apparatus 10 as soon as it has been acquired by the cameras 110, or can be transmitted at a later time than when it was acquired, for example when the drones have landed. The drones can have Global Positioning Systems (GPS) and this enables the location of acquired imagery to be determined. For example the orientation of cameras 110 and the position of the drone when imagery was acquired can be used to determine the geographical footprint of the image at the ground plane. The drones can also have inertial navigation systems, based for example on laser gyroscopes. In addition to being used to determine the orientation of the drone and hence of the camera, facilitating a determination of when on the ground the imagery has been acquired, the inertial navigation systems can function alone without a GPS system to determine the position of the drone, by determining movement away from a known or a number of known locations.

An input unit 20 of the apparatus 10 passes the acquired imagery to a processing unit 30. Image analysis software operates on the processor 30. The image analysis software can use feature extraction, such as edge detection, and object detection analysis that for example can identify structures such as railway tracks, sleepers, trees, level crossings, station platforms. Thus, on the basis of known locations of objects, such as the locations of buildings within the environment, and on the basis of known structure information such as the distance between sleepers and the distance between the railway tracks, the processing unit can patch the acquired imagery to in effect create a synthetic representation of the environment that can in effect be overlaid over a geographical map of the environment. Thus, the geographical location of each image can be determined, and there need not be associated GPS and/or inertial navigation based information associated with acquired

imagery. However, if there is GPS and/or inertial navigation information available, then such image analysis that can place specific images at specific geographical locations only on the basis of the imagery is not required. Although, if GPS and/or inertial navigation based information is available then such image analysis can be used to augment the geographical location associated with an image. Thus for example, if on the basis of GPS and/or inertial navigation based information the centre of an acquired image is deemed to be located 22cm from the side edge and 67cm from the end of a particular railway sleeper of a section of railway, whilst from the actual acquired imagery, through the use of the above described image analysis, the centre of the image is determined to be located 25cm from the edge and 64cm from the end of the sleeper, then the GPS/inertial navigation based derived location can be augmented by the shifting the location 3cm in one direction and 3cm in another direction as required.

The processor 30 runs further image processing software. This software analyses an image to determine the areas within the image where vegetation is to be found. Vegetation can be detected based on the shape of features within acquired images, where for example edge detection software is used to delineate the outer perimeter of objects and the outer perimeter of features within the outer perimeter of the object itself. A database of vegetation imagery can be used in helping determine if a feature in imagery relates to vegetation or note, using for example a trained machine learning algorithm such as an artificial neural network or decision tree analysis. The camera can acquire multi-spectral imagery, with imagery having information relating to the colour within images, and this can be used alone, or in combination with feature detection to determine where in an image vegetation is to be found. As discussed above, because the geographical location of an image can be determined, from knowledge of the size of an image on the ground, the location or locations of vegetation to be found in an image can then be mapped to the exact position of that vegetation on the ground.

The processor 30 then runs further image processing software that can be part of the vegetation location determined on the basis of feature extraction, if that is used. This software comprises a machine learning analyser. Images of specific weeds are acquired, with information also relating to the size of weeds being used. Information relating to a geographical location, in the world, where such a weed is to be found and information relating to a time of year when that weed is to be found, including when in flower etc. can be tagged with the imagery. The names of the weeds are also tagged with the imagery of the weeds. The machine learning analyser, which can be based on an artificial neural network or a decision tree analyser, is then trained on this ground truth acquired imagery.

In this way, when a new image of vegetation is presented to the analyser, where such an image can have an associated time stamp such as time of year, and a geographical location such as Germany or South Africa tagged to it, the analyser determines the specific type of weed that is in the image through a comparison of a imagery of a weed found in the new image with imagery of different weeds it has been trained on, where the size of weeds, and where and when they grow can also be taken into account. The specific location of that weed type on the ground within the environment, and its size, can therefore be determined. The processor 30 has a database containing different weed types, and the optimum weed control technology to be used in controlling that weed type. The size of the weed or clump of weeds on the ground can also be taken into account in determining which weed control technology (also called vegetation control technology) to be used. For example, a chemical spray may be the most optimum weed control technology for a particular type of weed. The processor can then determine that for a single weed or a small clump of this weed at a particular location in the environment the chemical spray weed control technology should be activated at that specific location to control the weeds. However, if there is a large clump of this specific type of weed that has been identified and located in the environment, the processor can determine that to mitigate the impact of the chemical on the environment a different weed control technology such as a flame based weed control, or a high voltage based weed control, or a steam or high pressure water based weed control technology, or a microwave based weed control technology should be used to control that larger clump of that specific weed at a specific location in the environment. The processor ensures that all weeds that need to be controlled, have assigned to them at least one weed control technology to be used. It could be the case that to best control a specific type of weed, two different types of weed control technology, for example microwave radiation and high voltage, should be applied and the processor creates the appropriate weed control map.

Thus, the cameras 110 of the drones acquire imagery of an environment that is passed to a processor 30 that determines what weed control technology should be applied at which specific geographical locations in the environment. Thus, in effect a weed map or a weed control technology map can be generated that indicates where within the environment specific weed control technologies should be used.

With continued reference to Fig. 4, a weed control train 130 progresses along the railway track. The weed control train has a number of trucks, each housing a weed control technology. A first truck has a chemical spray based weed control technology 120a. A second truck has a High Voltage based weed control technology 120b, other weed control technologies are laser based 120c, microwave based 120d and steam based 120e, and other

weed control technologies are available such as flame based, solid (foam) chemical deposition, and even mechanical based weed control technologies. The weed control train has a processor (not shown) which uses the above discussed weed map or weed control map. The weed control train has means to determine its geographical location, which can be based on one or more of GPS, inertial navigation, image analysis in order to locate the position of the weed control trains and the specific locations of the weed control technologies. This means that when the weed control train passes through the environment the different weed control technologies can be activated at the specific locations of weeds, where the specific weed control technology activated at the location of the weed has been determined to be optimal for that task. As discussed above, the weed control train can have a camera and acquire imagery. Acquired imagery can be processed by the processor on the weed control train to determine the location of the train itself, through determining the location of sleepers and features in the surroundings. Also, when the weed control train has a GPS and/or an inertial system, the GPS and/or inertial navigation systems can be used to determine the location of the train in order that the correct weed control technology can be activated at the location of specific weeds. However, if the train also has a camera acquiring imagery of the surrounding, feature extraction such as the position of sleepers etc. can be used to augment the position determined by GPS and/or inertial navigation to make corrections in position in order that the weed control technologies can activate at the exact locations of weeds, to take into account for example a position derived from the GPS system. Thus, the image processing required to determine the positions of sleepers can run quickly, with location updates being applied rapidly, because the complexity of image processing in locating features such as railway sleepers is not relatively large.

Fig. 5 shows another example of a system 100 for weed control. The system for weed control of Fig. 5 is similar to that shown in Fig. 4. However, in Fig. 5 the weed control train 130 has cameras 110 and an apparatus 10 as previously discussed. The cameras 110 on the weed control train 130 now acquire that imagery that was previously acquired by the drones. The processor 30 of the apparatus on the weed control train 130 processes the acquired imagery to determine the location and type of weed. The exact geographical location of the weed is not then required to be determined. Rather, on the basis of a relative spacing between the cameras 110 and the weed control technologies 120 on the train, an acquired image can be located at a specific point on the ground and weeds located and identified within that image and accordingly located on the ground, with the required weed control technology 120a, 120b, 120c, 120d, or 120e to be activated at the location of the

weed being determined. Then, from knowledge of the forward motion of the weed control train (its speed) and the time when an image was acquired, it can be determined when the required weed control technology should be activated such that it activates at the position of the weed. In this way, the weed control train does not need to have a GPS and/or inertial navigation system or image based absolute geographical location determination means. Rather, to account for the processing required to determine the type of weed and its exact location within an image and its exact location on the ground – within a train coordinate system – the cameras 110 must be spaced from the weed control technologies 120 by a distance that is at least equal to the processing time multiplied by the maximum velocity of the weed control train during weed control. Thus for example, if processing takes 0.2s, 0.4s, or 0.8s for a train travelling at 25m/s, with reference to Fig. 5 the cameras 110 must be spaced forward of weed control technology 120e by 5m, 10m or 20m for this train velocity. A reduction in train velocity enables the separation to be reduced. In addition, the cameras 110 that are acquiring the imagery can have very short exposure times in order that image smear due to movement of the train during the exposure time is minimized. This can be by various means, including the use of cameras with short exposure times or short pulsed illumination via for example lasers or LEDs in combination with filters for example. However, the apparatus can use a GPS system and/or inertial navigation system and/or image analysis to determine an exact geographical location of weeds. This means that a log of what weeds have been controlled by what weed control means, and where those weeds were located can be determined. Also, by generating an exact geographical location of the weeds, the weed control technologies 120a-120a can have associated location determining means, such as a GPS system and/or inertial navigation system and/or image based system that can be used to provide the exact position of the specific weed control technology. Thus, a front carriage of a train can have the image acquisition and analysis units that enable a weed control map to be constructed. The last few trucks of a train could then have the weed control technologies housed within them, where these latter trucks could be spaced from the front carriage by many tens if not hundreds of metres by load carrying trucks. The absolute separation of the front carriage to the rear carriages could then vary as the train goes up and down hill, but because the trucks with the weed control technologies know their exact locations, when they have moved forwards to the position of a weed or areas of weeds of a particular type, the appropriate weed control technology can be activated at that precise geographical location.

Fig. 5 shows two views of the weed control train 130, the top being a side view and the bottom showing a plan view. This shows the cameras 110 acquiring imagery that extends

between the tracks and to the sides of the tracks. The individual trucks of the weed control train have the associated weed control technology that can be applied beneath the train and to the side of the train.

Fig. 6 shows a truck of the weed control train 130 as shown in Figs 4-5, that has a chemical spray based weed control technology 120a. Fig. 6 shows a rear view of this truck of the train, with the view being that down the railway track. A number of separate spray nozzles of the weed control technology 120a extend laterally beneath the train and to the sides of the train. A spray nozzle can itself have now specific control, outside of being on or off, or can be directionally controlled to spray to the left and of right or downwards, and/or to be controlled such that the angular extent of the spray is varied in order that for example a narrow jet of spray can be directed to a single weed. When one of these spray nozzles passes over a weed that has been identified as one that should be controlled by chemical spray the processor 30 activates the specific nozzle that sprays chemical at the specific location of the weed that is required to be controlled by a chemical spray. In Fig. 6 there are two specific locations of such a weed, one to be found between the track and one to the left of the tracks, and accordingly two spray nozzles have been activated. It is to be noted that weeds can pass under this truck that have already had one of the other weed control technologies 120b-e applied to them.

Fig. 7 shows a truck of the weed control train 130 as shown in Figs 4-5, that has a high voltage based weed control technology 120b. Fig. 7 shows a rear view of this truck of the train, with the view being that down the railway track. A number of separate electrode pairs of the weed control technology 120b extend laterally beneath the train and to the sides of the train, with these shown in greater detail in Fig. 9. When one of these electrode pairs passes over a weed that has been identified as one that should be controlled by high voltage based weed control the processor 30 activates the specific pair or pairs of electrodes at the specific location of the weed that is required to be controlled by high voltage. In Fig. 7 there are two specific locations of such a weed, one a large clump to be found between the track that also extends to the right hand side of the track and a small clump to be found to the left of the tracks, and accordingly one electrode pair has been activated at the left hand side and a number activated beneath the train extending to the right hand side. It is to be noted that weeds can pass under this truck that have already had one of the other weed control technologies 120c-e applied to them, and weeds can pass

under the truck in an untreated state if it has been determined that they should be addressed by the chemical spray based weed control technology 120a.

Fig. 8 shows a truck of the weed control train 130 as shown in Figs 4-5, that has a laser based weed control technology 120c. Fig. 8 shows a rear view of this truck of the train, with the view being that down the railway track. A number of separate laser systems of the weed control technology 120c extend laterally beneath the train and to the sides of the train. Each laser system can simply operate in an on/off state illuminating the area under the laser system or can also be directionally steered as required in order that only the specific location of the weed is illuminated. When one of these laser systems passes over a weed that has been identified as one that should be controlled by laser radiation based weed control the processor 30 activates the specific laser systems at the specific location of the weed that is required to be controlled by laser radiation. In Fig. 8 there is only one specific location of such a weed, that is located near to the left hand side track just between the tracks, and accordingly one laser system has been activated beneath the train with the laser radiation directed towards the specific location of the weed. The laser systems can be laser diode based, Nd:YAG based, Excimer based or any other laser system that has been indicated as being suitable for weed control. It is to be noted that weeds can pass under this truck that have already had one of the other weed control technologies 120d-e applied to them, and weeds can pass under the truck in an untreated state if it has been determined that they should be addressed by the chemical spray based weed control technology 120a and/or the high voltage based weed control technology 120b.

Fig. 9 shows more detail of the high voltage based weed control technology 120b. Pairs of electrodes are provided, which when activated cause electric current to flow from one electrode to the other via the weed and the ground including the weed's root. One sub-unit shown in Fig 120b can have one electrode pair or indeed have a number of electrode pairs in order to provide for greater resolution and a smaller spatial extent of the application of such high voltage based weed control. The high voltage can be applied in a DC mode for a period of time or in an AC mode for a period of time.

Fig. 10 shows a representation of a railway environment, showing the railway tracks and the ground to the side of the tracks. A number of weed areas are shown, with a large clump of one type of weed having a clump of a different type of weed within it. Shown in Fig. 10 are the specific weed control technologies that have been determined to be activated for these specific weeds. This can be considered to be the weed control map discussed with

respect to Fig. 4, or the real-time determination of what weed control technology should be applied where discussed with respect to Fig. 5.

The above detailed examples have been discussed with respect to a railway, where different weed control technologies (vegetation control technologies) are housed in different trucks of the train. These could be housed in a single truck, and there could be just two, three or four weed control technologies, for example just chemical spray and high voltage technologies. Additionally, rather than a weed control train, a truck or lorry or Unimog can have a number of weed control technologies mounted on/within it and, on the basis of previously acquired and processed imagery or on the basis of imagery it acquires and processes itself, drive around an industrial area or even an area such as an airport and apply specific weed control technologies to specific weed types as discussed above.

In another exemplary embodiment, a computer program or computer program element is provided that is characterized by being configured to execute the method steps of the method according to one of the preceding embodiments, on an appropriate system.
The computer program element might therefore be stored on a computer unit, which might also be part of an embodiment. This computing unit may be configured to perform or induce performing of the steps of the method described above. Moreover, it may be configured to operate the components of the above described apparatus and/or system. The computing unit can be configured to operate automatically and/or to execute the orders of a user. A computer program may be loaded into a working memory of a data processor. The data processor may thus be equipped to carry out the method according to one of the preceding embodiments.
This exemplary embodiment of the invention covers both, a computer program that right from the beginning uses the invention and computer program that by means of an update turns an existing program into a program that uses invention.
Further on, the computer program element might be able to provide all necessary steps to fulfill the procedure of an exemplary embodiment of the method as described above.

According to a further exemplary embodiment of the present invention, a computer readable medium, such as a CD-ROM, USB stick or the like, is presented wherein the computer readable medium has a computer program element stored on it which computer program element is described by the preceding section.

A computer program may be stored and/or distributed on a suitable medium, such as an optical storage medium or a solid state medium supplied together with or as part of other hardware, but may also be distributed in other forms, such as via the internet or other wired or wireless telecommunication systems.

However, the computer program may also be presented over a network like the World Wide Web and can be downloaded into the working memory of a data processor from such a network. According to a further exemplary embodiment of the present invention, a medium for making a computer program element available for downloading is provided, which computer program element is arranged to perform a method according to one of the previously described embodiments of the invention.

It has to be noted that embodiments of the invention are described with reference to different subject matters. In particular, some embodiments are described with reference to method type claims whereas other embodiments are described with reference to the device type claims. However, a person skilled in the art will gather from the above and the following description that, unless otherwise notified, in addition to any combination of features belonging to one type of subject matter also any combination between features relating to different subject matters is considered to be disclosed with this application. However, all features can be combined providing synergetic effects that are more than the simple summation of the features.

While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive. The invention is not limited to the disclosed embodiments. Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing a claimed invention, from a study of the drawings, the disclosure, and the dependent claims.

In the claims, the word “comprising” does not exclude other elements or steps, and the indefinite article “a” or “an” does not exclude a plurality. A single processor or other unit may fulfill the functions of several items re-cited in the claims. The mere fact that certain measures are re-cited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

Claims:

1. An apparatus (10) for weed control, comprising:

- an input unit (20);
- a processing unit (30); and
- an output unit (40);

wherein, the input unit is configured to provide the processing unit with at least one image of an environment;

wherein, the processing unit is configured to analyse the at least one image to determine at least one vegetation control technology from a plurality of vegetation control technologies to be used for weed control for at least a first part of the environment; and

wherein the output unit is configured to output information useable to activate the at least one vegetation control technology.

2. Apparatus according to claim 1, wherein analysis of the at least one image to determine at least one vegetation control technology comprises a determination of at least one location of vegetation in the at least first part of the environment, and wherein the processing unit is configured to determine the at least one vegetation control technology to be used at that at least one location.

3. Apparatus according to any of claims 1-2, wherein the at least one image was acquired by at least one camera, and wherein the input unit is configured to provide the processing unit with at least one location associated with the at least one camera when the at least one image was acquired.

4. Apparatus according to any of claims 1-3, wherein analysis of the at least one image to determine the at least one vegetation control technology comprises a determination of at least one type of weed.

5. Apparatus according to claim 4, wherein the processing unit is configured to determine at least one location of the at least one type of weed.

6. Apparatus according to any of claims 1-5, wherein analysis of the at least one image to determine the at least one vegetation control technology comprises a determination of a first type of weed in the at least first part of the environment and a determination of a second type of weed in at least a second part of the environment.

7. Apparatus according to claim 6, wherein the processing unit is configured to analyse the at least one image to determine a first vegetation control technology to be used for weed control for the first type of weed in the at least the first part of the environment; and wherein the processing unit is configured to analyse the at least one image to determine a second vegetation control technology to be used for weed control for the second type of weed in at least a second part of the environment.

8. Apparatus according to any of claims 1-7, wherein the processing unit is configured to analyse the at least one image to determine a first vegetation control technology from the plurality of vegetation control technologies to be used for weed control for at least the first part of the environment; and wherein the processing unit is configured to analyse the at least one image to determine a second vegetation control technology from the plurality of vegetation control technologies to be used for weed control for at least a second part of the environment.

9. Apparatus according to any of claims 1-8, wherein analysis of the at least one image comprises utilisation of a machine learning algorithm.

10. A system (100) for weed control, comprising:

- at least one camera (110);
- an apparatus (10) for weed control according to any of claims 1-9; and
- at least one vegetation control technology (120);

wherein, the at least one camera is configured to acquire the at least one image of the environment;

wherein, the at least one vegetation control technology is mounted on a vehicle (130); and

wherein, the apparatus is configured to activate the at least one vegetation control technology for the at least first part of the environment.

11. System according to claim 10, wherein the apparatus is mounted on the vehicle; and wherein the at least one camera is mounted on the vehicle.

12. A method (200) for weed control, comprising:

(a) providing (210) a processing unit with at least one image of an environment;

(c) analysing (220) by the processing unit the at least one image to determine at least one vegetation control technology from a plurality of vegetation control technologies to be used for weed control for at least a first part of the environment; and

(e) outputting (230) information by an output unit that is useable to activate the at least one vegetation control technology.

13. Method according to claim 12, wherein step c) comprises step determining (240) at least one location of vegetation in the at least first part of the environment; and wherein the method comprises step d) determining (250) by the processing unit the at least one vegetation control technology to be used at that at least one location.

14. Method according to any of claims 12-13, wherein in step a) the at least one image was acquired by at least one camera; and wherein the method comprises step b) providing (260) the processing unit with at least one location associated with the at least one camera when the at least one image was acquired.

15. A computer program element for controlling an apparatus according to any of claims 1 to 9 and/or system according to any of claims 10-11, which when executed by a processor is configured to carry out the method of any of claims 12-14.

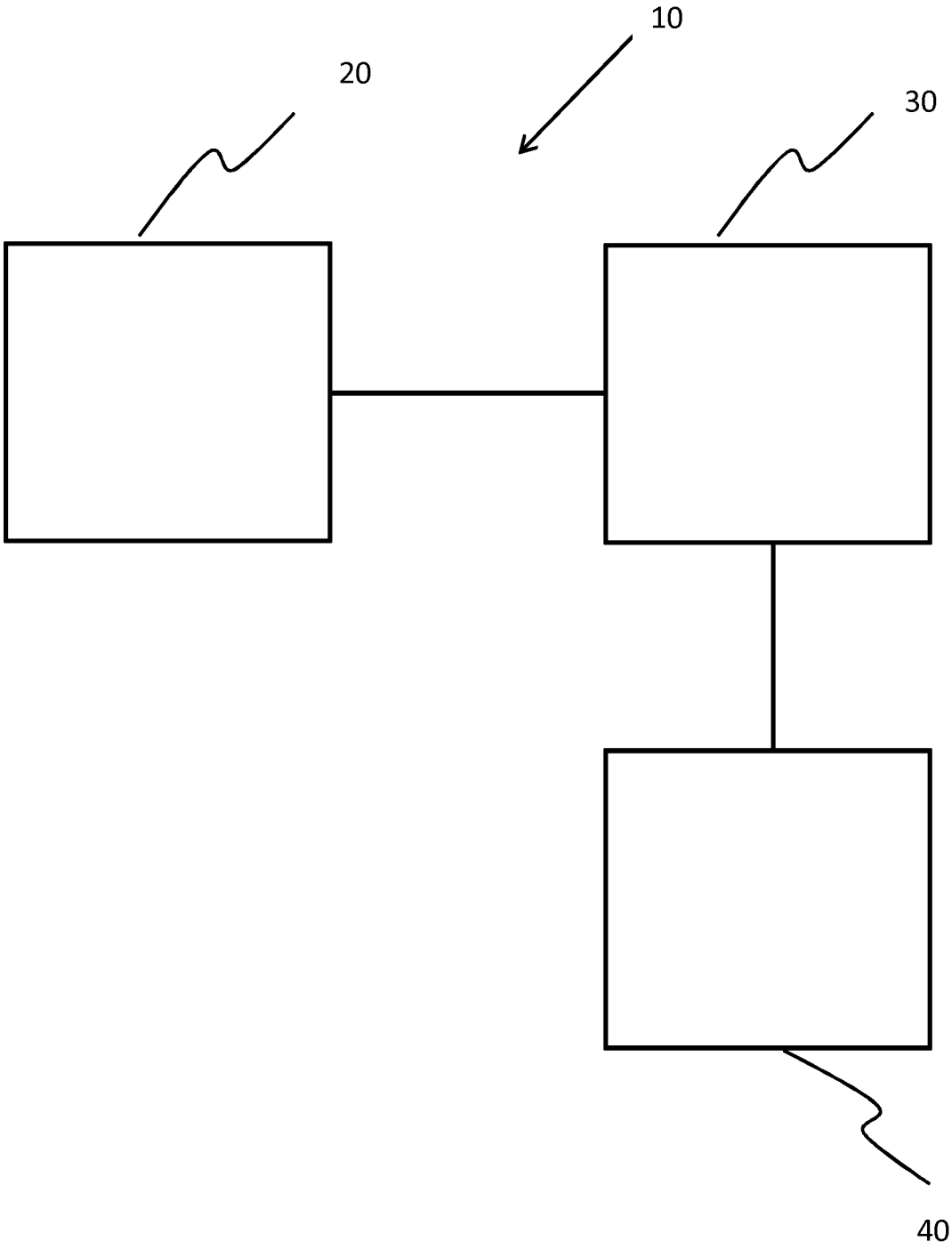


Fig. 1

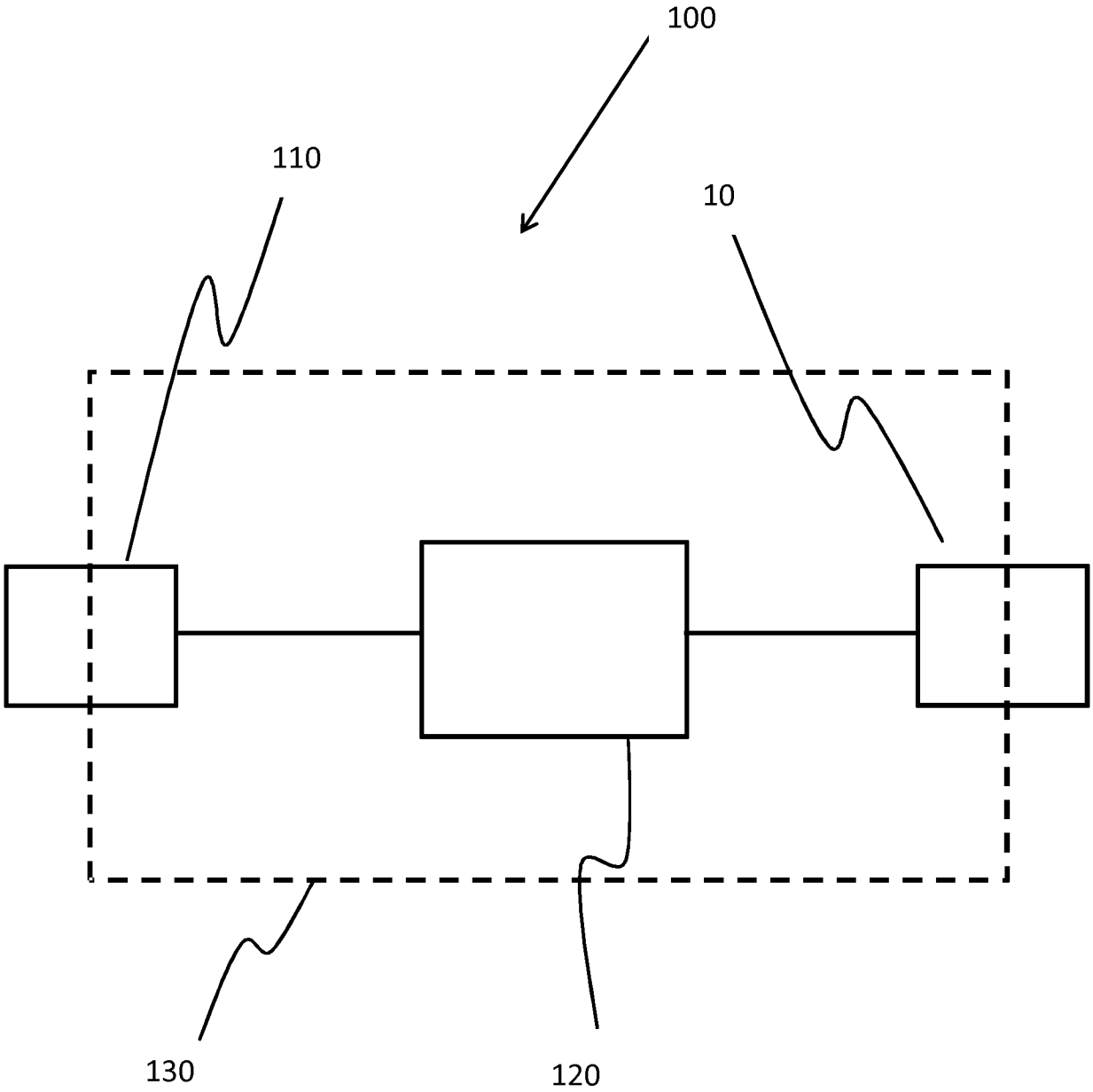
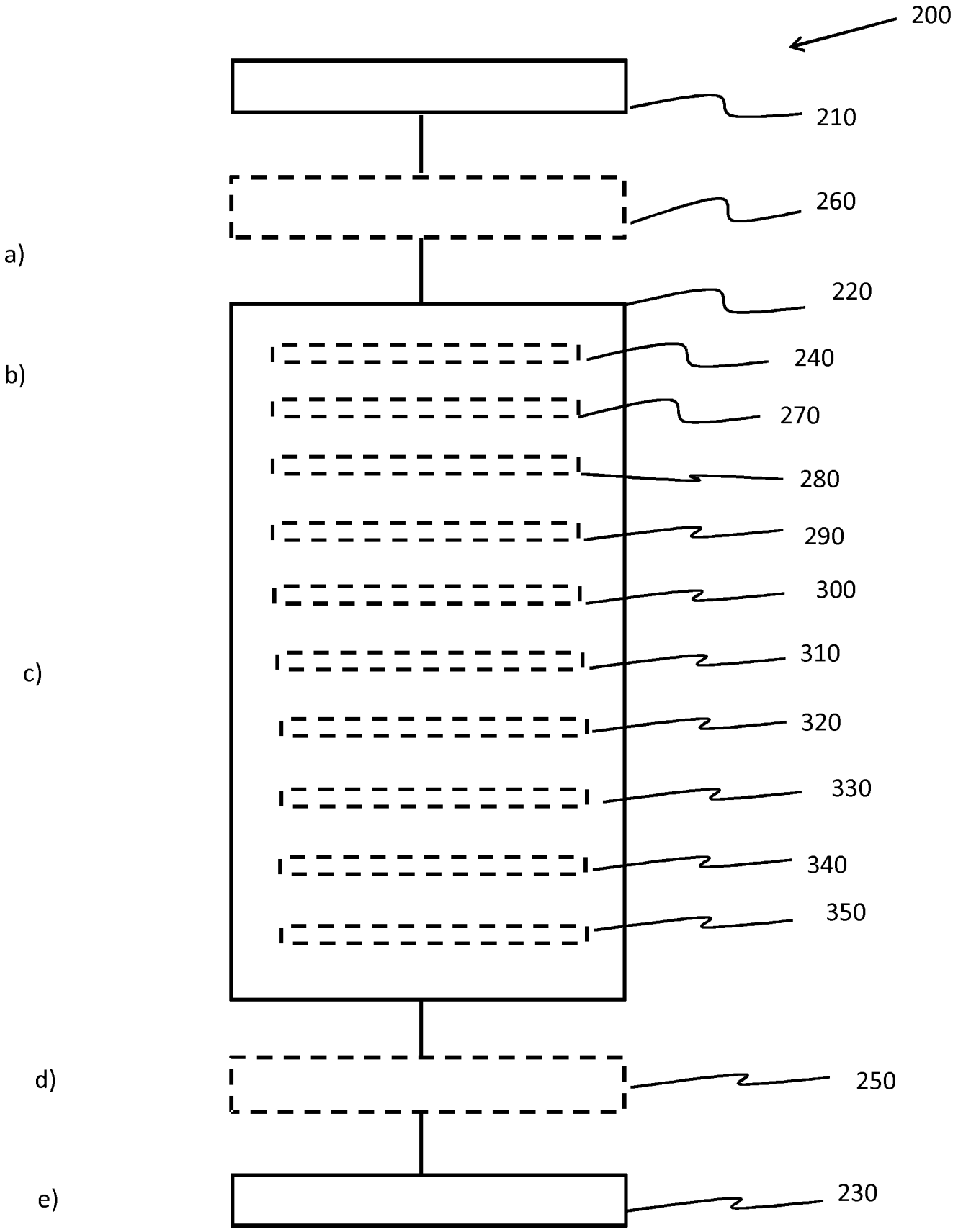


Fig. 2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260
a)
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e)
230

Fig. 3

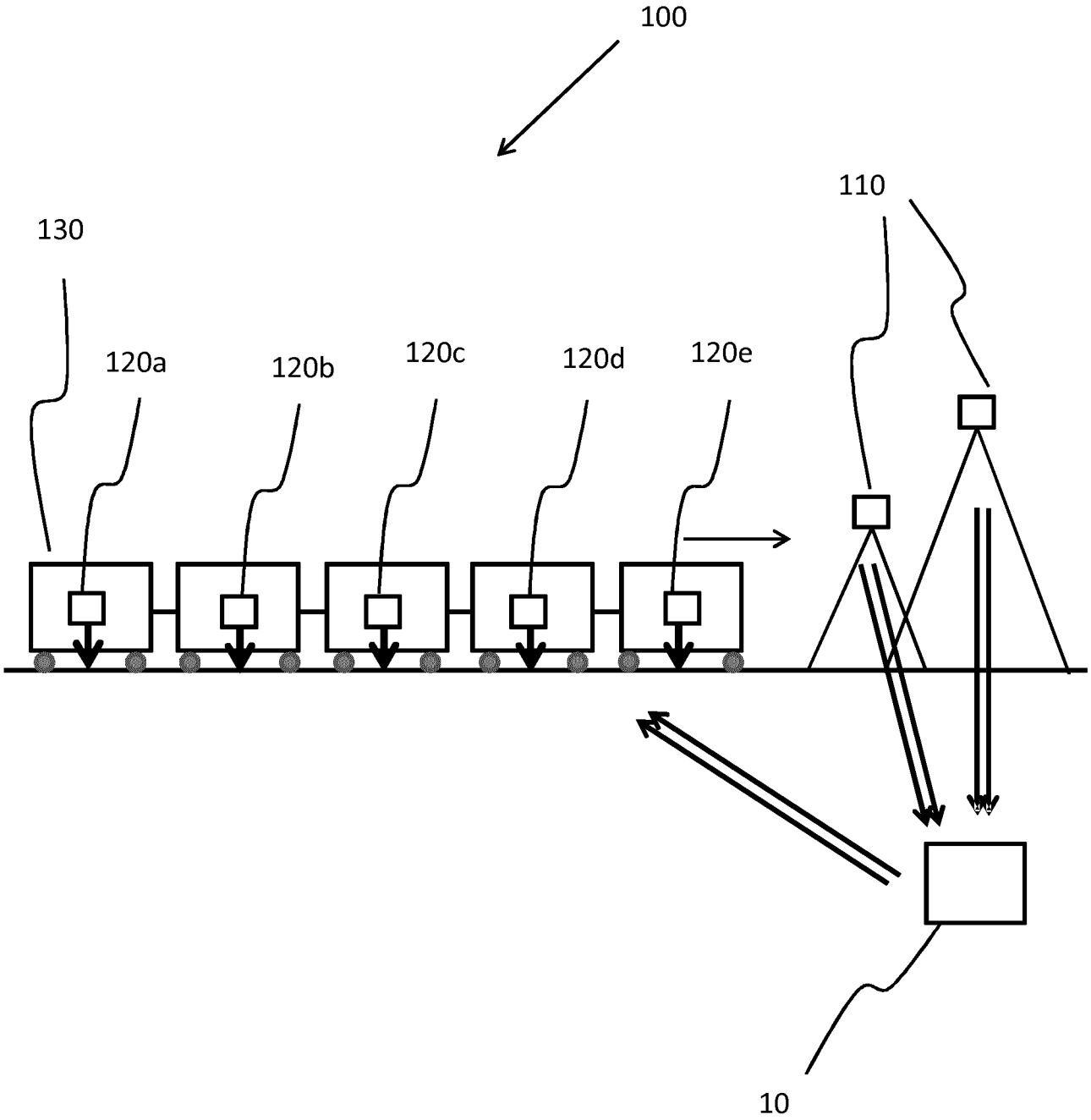
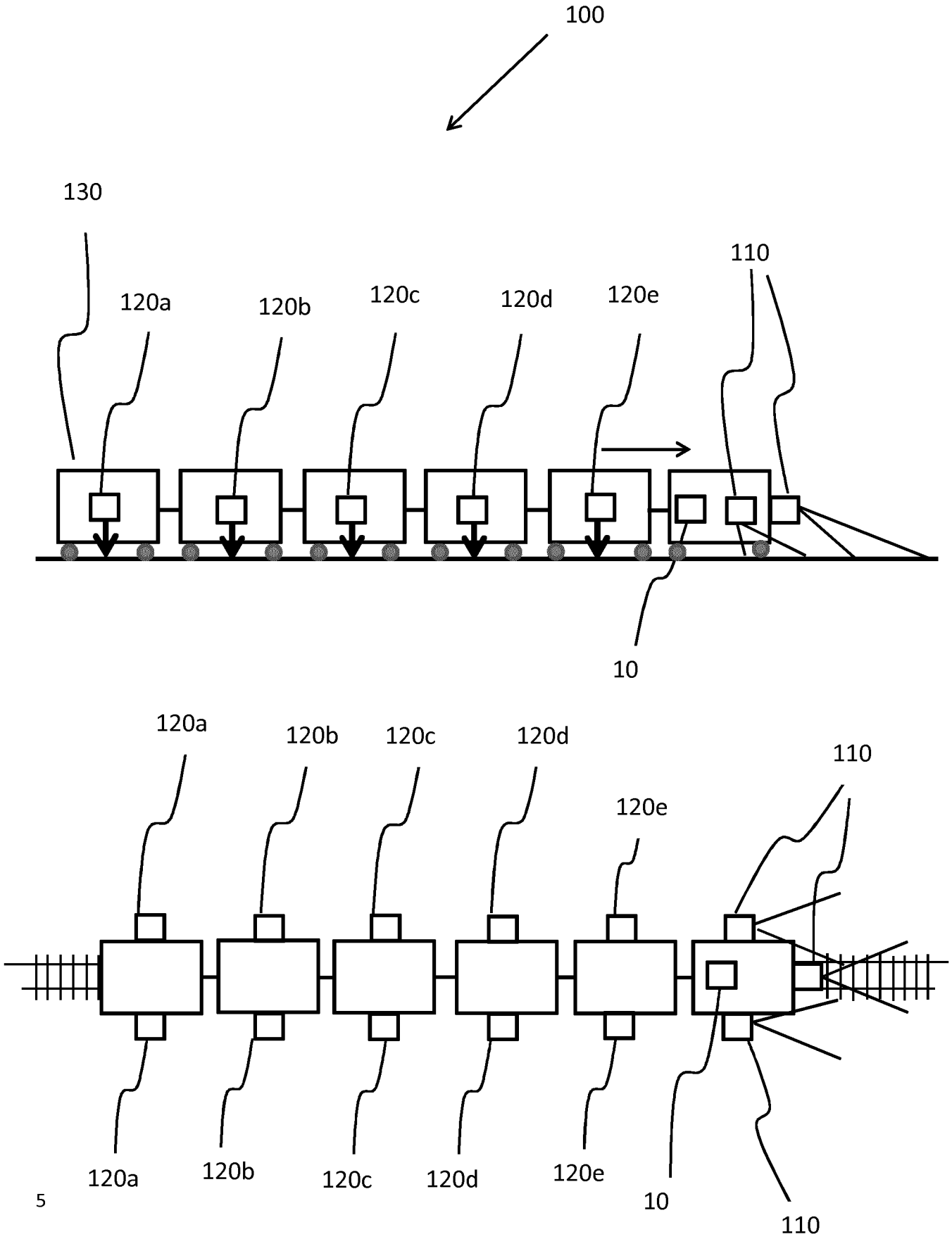


Fig. 4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130
120a
120b
120c
120d
120e
110
10
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120b
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120e
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120a
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10
110

Fig. 5

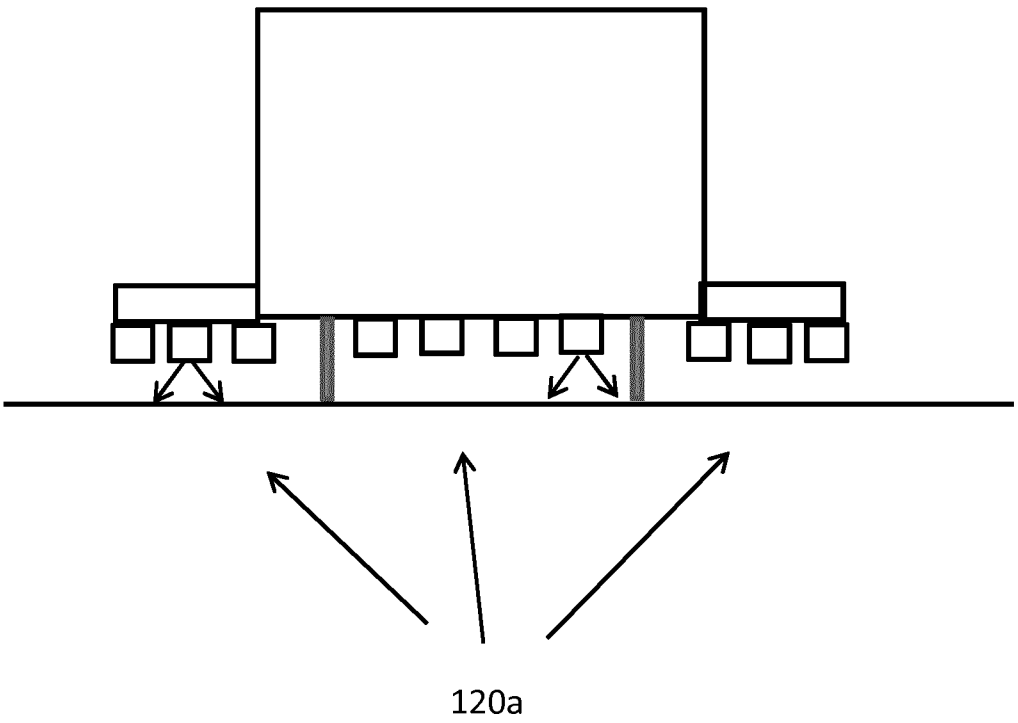

Fig. 6

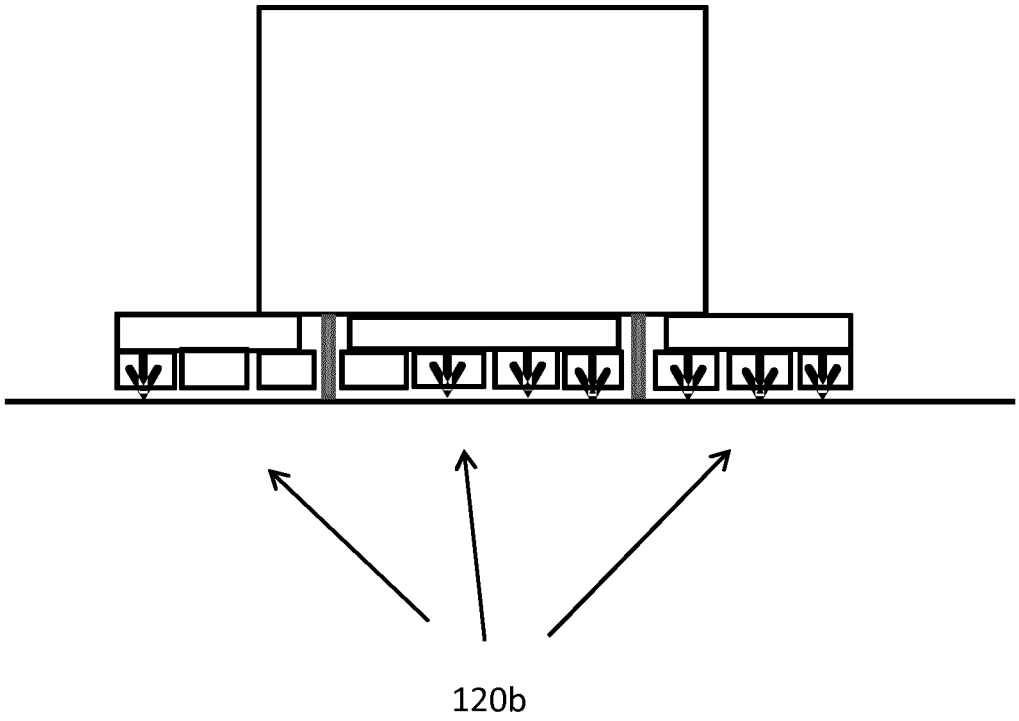

Fig. 7

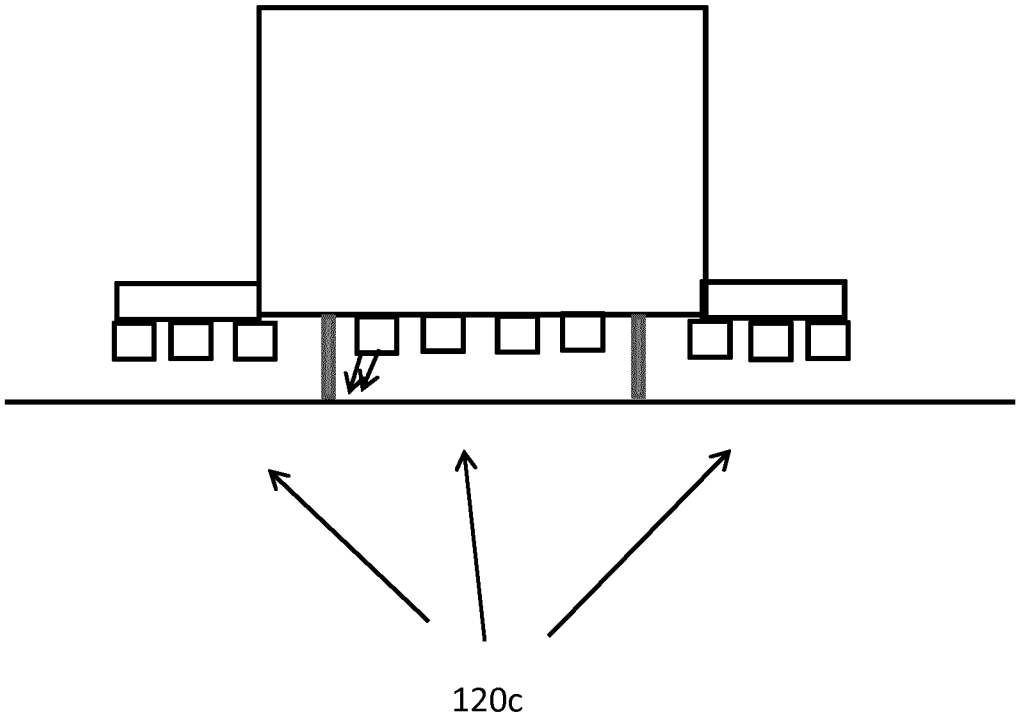

Fig. 8

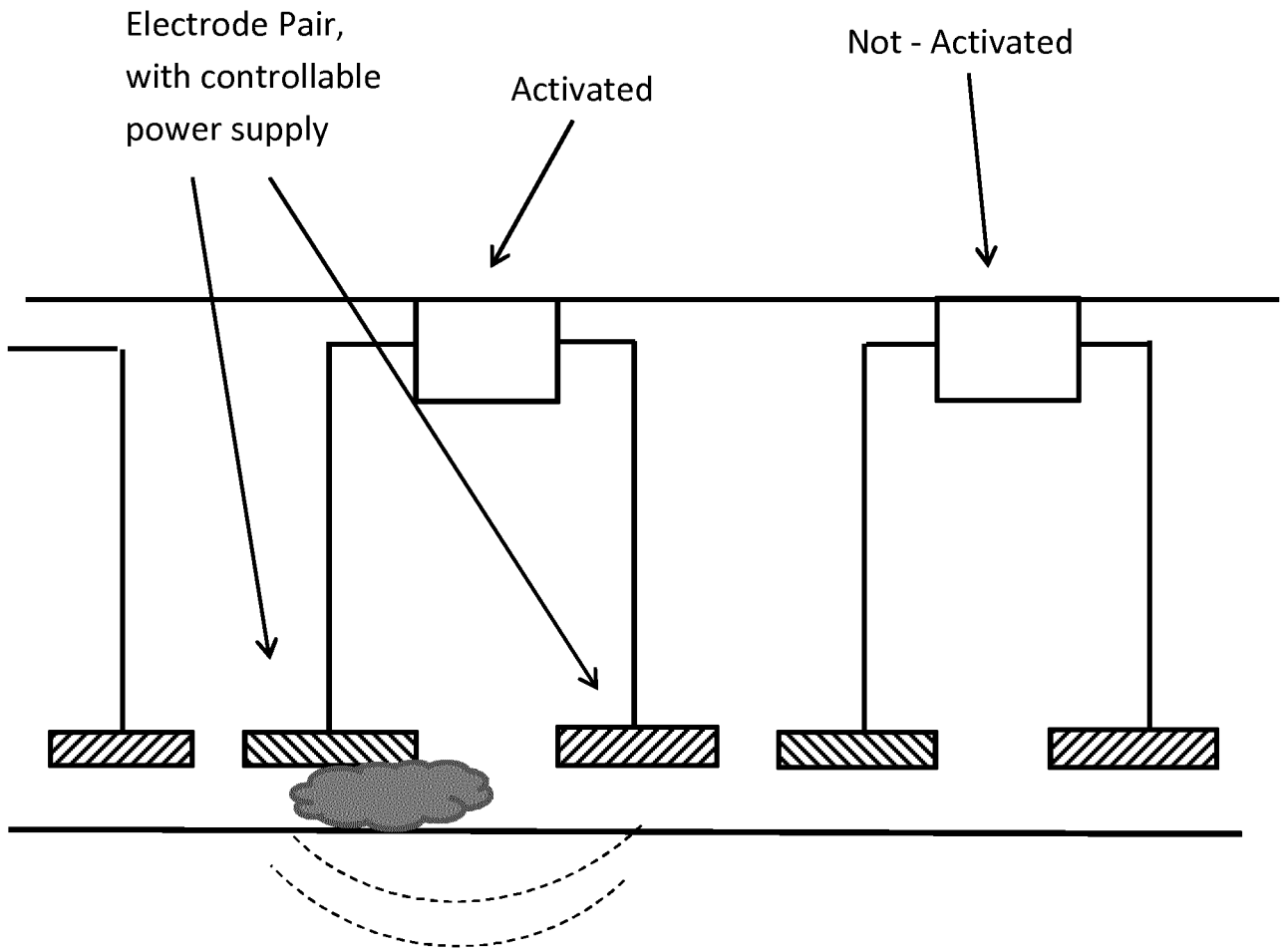
Electrode Pair,
with controllable
power supply
Activated
Not - Activated
Electric Current Flow
through vegetation
and ground
120b

Fig. 9

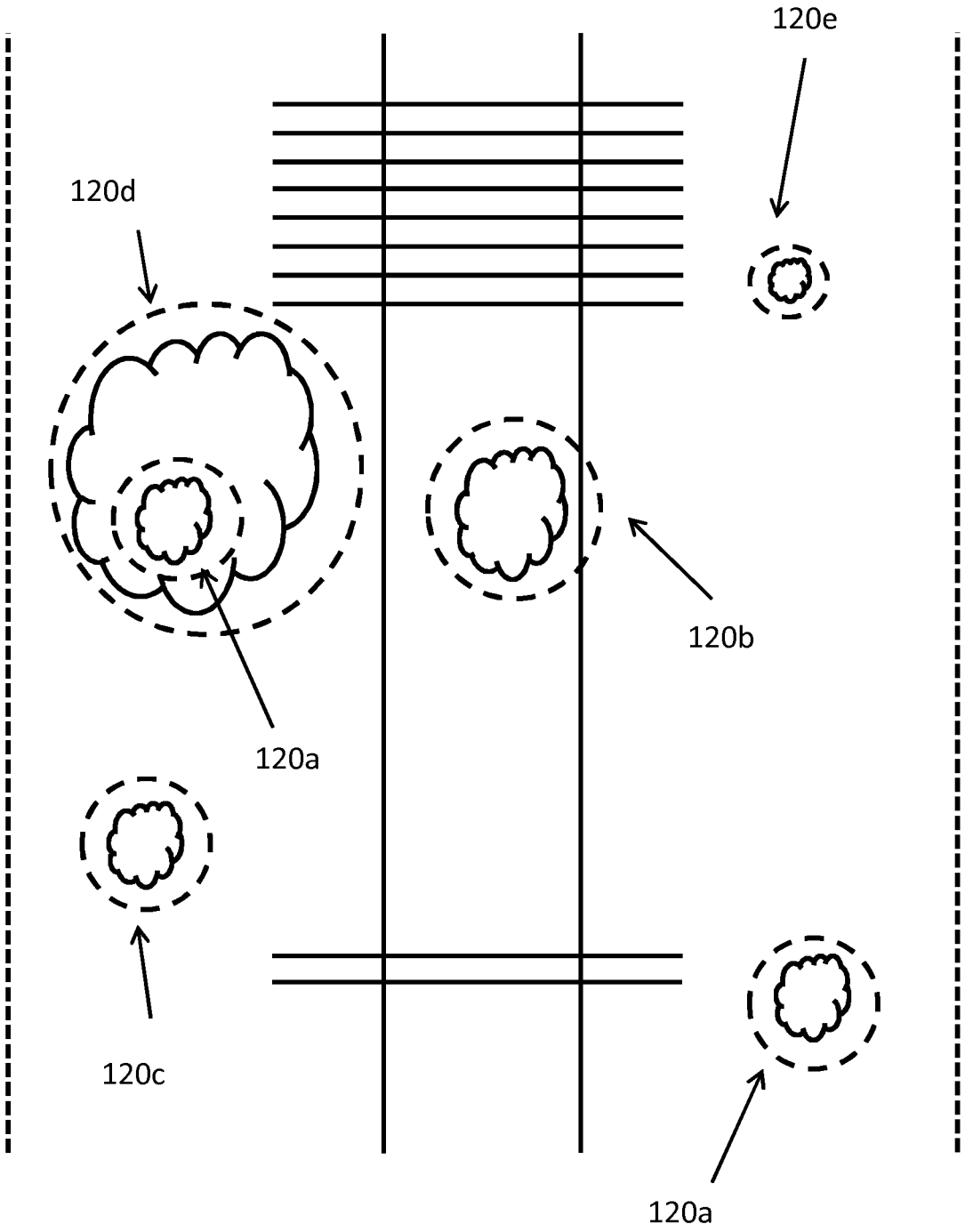

Fig. 10

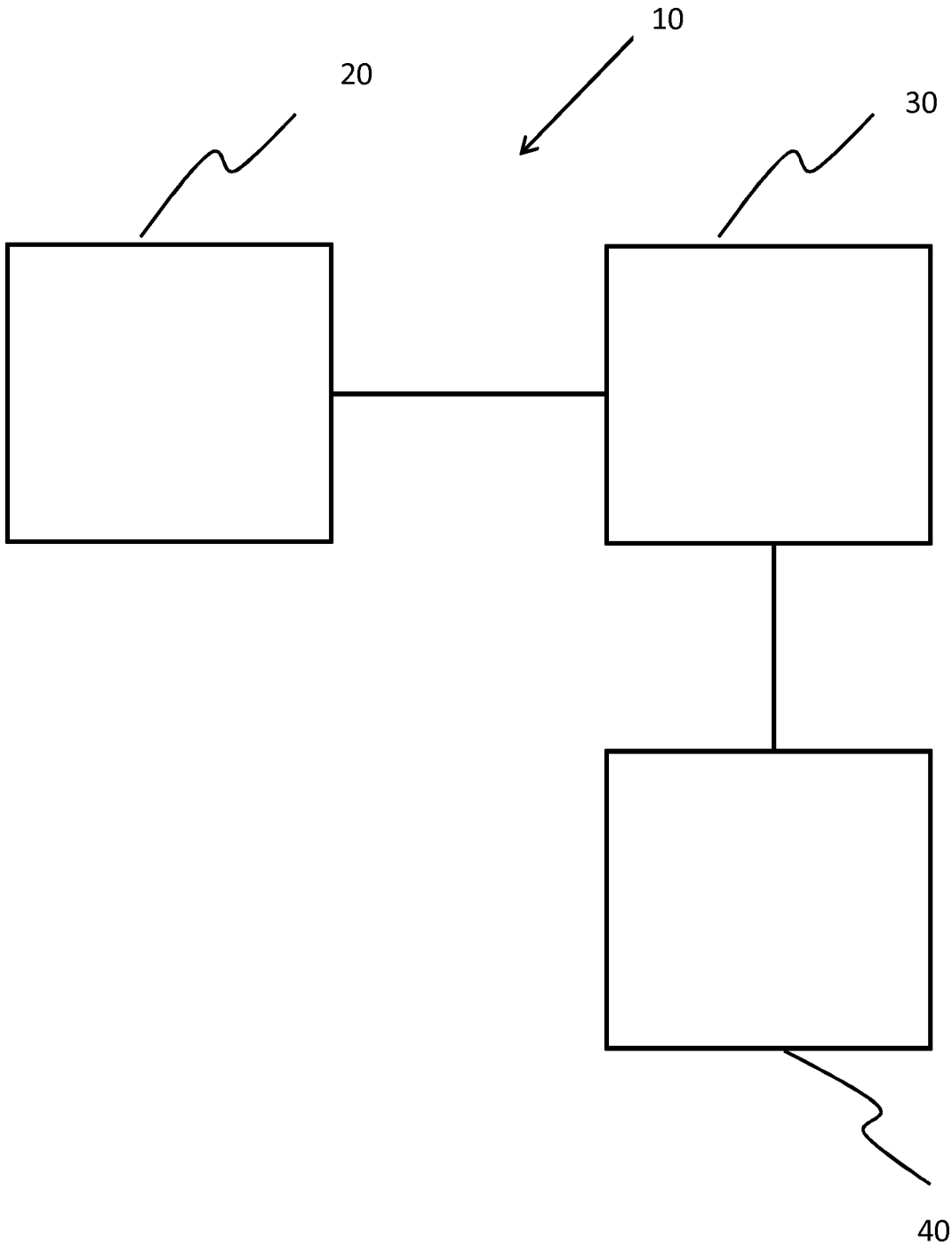

Fig. 1