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(FI)

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(71) Hakija - Sökande - Applicant

1 • Novatron Oy, Tampere, Jasperintie 312, 33960 PIRKKALA, SUOMI - FINLAND, (FI)

(72) Keksijä - Uppfinnare - Inventor

1 • Hokkanen, Visa, PIRKKALA, SUOMI - FINLAND, (FI)
2 • Vesanen, Mikko, PIRKKALA, SUOMI - FINLAND, (FI)

(74) Asiamies - Ombud - Agent

Kolster Oy Ab, Salmisaarenaukio 1, 00180 Helsinki

(54) Keksinnön nimitys - Uppfinningens benämning - Title of the invention

Maansiirtokoneiden ohjaus

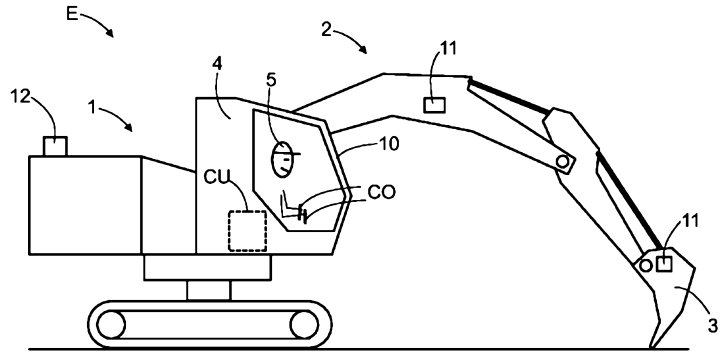
Styrning av schaktmaskiner

CONTROLLING EARTHMOVING MACHINES

(57) Tiivistelmä - Sammandrag - Abstract

Keksintö perustuu ajatukseen ohjata kuljettajan (5) ohjattavissa olevia maansiirtokoneen (**E**) toimintoja käyttämällä ainoastaan yhdestä neljään ohjainta (CO) ja ainakin yhtä näyttövälinettä esittämään yhdestä neljään ohjaimella (CO) valittavissa ja ohjattavissa olevia ohjauksia. Toimintojen valinnat ja ohjaukset maansiirtokoneen (**E**) ohjaamiseksi voidaan siirtää ohjausyksikköön (CU) sekä langallisesti että langattomasti. Siten yhdestä neljään ohjainta (CO) ovat käytettävissä sekä liitettyinä että kytkettyinä irti. Edelleen ohjausjärjestelmä (CS) on järjestetty määrittämään yhdestä neljään ohjaimen (CO) sijainti maansiirtokoneen (**E**) suhteen.

The invention is based on the idea of controlling the operations of the earthmoving machine (**E**) controllable by the operator (5) by using only one to four controllers (CO) and at least one displaying means for displaying controls selectable and controllable by the one to four controllers (CO). The selections and controls of the operations for controlling the earthmoving machine (**E**) may be transmitted to control unit (CU) both by wire and wirelessly. Thus, the one to four controllers (CO) are operable both attached and detached. Further, the control system (CS) is arranged to determine the loction of the one to four controllers (CO) with respect to the earthmoving machine (**E**).



CONTROLLING EARTHMOVING MACHINES

FIELD OF THE INVENTION

The invention relates to a control system, an apparatus, a computer program product and a computer program embodied on a non-transitory computer readable storage medium for controlling an earthmoving machine.

BACKGROUND OF THE INVENTION

Different types of earthmoving machines may be utilized at different work sites for moving soil or rock material to another location or to process them into a desired shape. Earthmoving machines are used in excavation work and road construction, for example. Earthmoving machines have user interfaces containing multiple controllers and multiple displaying means for an operator to interact with the earthmoving machine.

BRIEF DESCRIPTION OF THE INVENTION

An object of the present invention is to provide a novel and improved control system for an earthmoving machine. Further object is to provide a novel and improved earthmoving machine equipped with the control system.

The objects of the invention are achieved by what is stated in the independent claims. Embodiments of the invention are disclosed in the dependent claims.

The invention is based on the idea of controlling the operations of the earthmoving machine controllable by the operator by using only one to four controllers and at least one displaying means for displaying controls selectable and controllable by the one to four controllers. The selections and controls of the operations for controlling the earthmoving machine may be transmitted to control unit both by wire and wirelessly. Thus, the one to four controllers are operable both attached and detached. Further, the control system is arranged to determine the loction of the one to four controllers with respect to the earthmoving machine.

An advantage of the control system of the invention is that the operator of the earthmoving machine may customize the way for controlling the operations of the earthmoving machine with the one to four controllers according to his or her own desires. Another advantage is that the operator need not to reach out any other buttons or switches in any case if desired.

According to an embodiment, the operation mode of the one to four controllers in the disclosed control system depends on whether each of the one to four controllers are attached or detached.

According to an embodiment, the operation mode of each of the one to four controllers, when detached, depends on the distance between these controllers and the earthmoving machine.

According to an embodiment, the operation mode of each of the one to four controllers, when detached, depends on the distance between these controllers and the earthmoving tool of the earthmoving machine.

According to an embodiment, the operation mode of each of the one to four controllers, when detached, depends on the distance between each other.

According to an embodiment, the operation mode of each of the one to four controllers depends on the distance between a detected obstacle and the earthmoving tool or the earthmoving machine.

According to an embodiment, the operation mode of the one to four controllers depends on the user specified adjustments made by or made for the user currently logged in to the control system.

According to an embodiment, the extent of the available adjustments depends on the skill level data of the user currently logged in, the skill level data being defined by at least one of: usage hours of the earthmoving machine, usage hours of the respective earthmoving machine, competence level accomplished or passed by an examination or test.

According to an embodiment, the operation of the earthmoving machine controllable by the one to four controllers is at least one of: driving system, peripheral device, maintenance system, road navigation system, work site navigation system, positioning the earthmoving tool with respect to the work site, weighing system, automation system, measuring system and process control.

According to an embodiment, the control system gives feedback by at least one of the following signals: graphical, augmented reality, virtual reality, audiovisual, visual illumination, haptics and force-feedback.

According to an embodiment, the user with administrator privileges define the skill level by editing the skill level data of the user.

According to an embodiment, the user with administrator privileges define the skill level by editing the skill level data of the user in a cloud service and the earthmoving machine retrieves the data from the cloud service.

According to an embodiment, the at least one control unit is configured to receive selections and controls from the one to four controllers for controlling at least the tool and the driving of the earthmoving machine.

According to an embodiment, the at least one control unit is configured to receive selections and controls from the one to four controllers for controlling all the operations of the earthmoving machine controllable by the operator of the earthmoving machine.

According to an embodiment, the amount of controllers is two.

According to an embodiment, the earthmoving machine is one of the following: excavator, bulldozer, motor grader, compaction machine, piling machine, deep stabilization machine, surface top drilling machine.

The above-disclosed embodiments may be combined to form suitable solutions provided with necessary features disclosed.

BRIEF DESCRIPTION OF THE DRAWINGS

Some embodiments are described in more detail in the accompanying drawings, in which

Figure 1 is a schematic side view of an excavating machine provided with two controllers,

Figure 2 is a schematic view of an operator operating an earthmoving machine outside the cabin,

Figure 3 is a schematic diagram showing some feasible earthmoving machines,

Figures 4a – 4c are schematic side views of some possible arrangements for displaying earthmoving images on a transparent display unit,

Figure 5 is a schematic front view of a headset provided with one or two head-mounted display units, and

Figure 6 is a schematic front view of a helmet provided with a head-mounted display unit.

For the sake of clarity, the figures show some embodiments of the disclosed solution in a simplified manner. In the figures, like reference numerals identify like elements.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 shows an earthmoving machine E, which is in this case an excavator comprising a movable carrier 1 on which a boom 2 is arranged. At a distal end of the boom 2 is a tool 3, in this case a bucket. The boom 2 may be moved in a

versatile manner. The operator 5 may select the manner how the boom 2 and the bucket responds to the controls of the controllers CO. The user may prefer in some cases semiautomatic controlling, where the bucket moves in a preconfigured or preprogrammed manner according to given controls and in the other cases the user may prefer more traditional way, for example, by controlling the bucket such that each joint in the boom 2 and the bucket are controlled separately.

On the carrier 1 is a control cabin 4 for an operator 5. Inside the cabin 4 is a displaying means, which comprises, for example, at least one transparent display unit 6 through which the operator 5 may monitor operation of the tool 3 and display controls selectable and controllable. The display unit 6 may also be some other kind. Additionally, the displaying means, part of the displaying means or the display unit 6 may be wireless or detachable like the controllers CO.

Figure 1 further discloses that the earthmoving machine E and its operational components may be equipped with sensors 11 and measuring devices for gathering position data and sense the surroundings and the location of the controllers CO, for example. Moreover, the earthmoving machine E may comprise one or more navigation or position determining systems 12, such as a global navigation satellite system (GNSS), for determining position and direction of the earthmoving machine E.

According to an embodiment, skill level, user account or both may at least one of force, entitle, deny and limit the usage of at least some controls, features or both.

According to an embodiment, an experienced operator 5 desires to use four controllers CO, one for both hands and one for both feet, and the semiautomatic controls where the operator 5 may control the bucket, for example, to go left, right, forward, backward, up and down. The operator 5 may also select at which degree with respect to horizontal or vertical plane the bucket goes to these directions. The controllers CO used by feet he desires to drive the earthmoving machine E. The other foot may control the speed and whether to go forward or backward and the other foot may control whether to go straight or to turn left or right, for example.

The user may select from various alternatives which kind of feedback signals he or she desires at each situation in each earthmoving machine E. Selectable feedback signals are at least: graphical, augmented reality, virtual reality, audiovisual, visual illumination, haptics and force-feedback.

Automatic or semiautomatic controls, as well as any other data relating to earthmoving machine E, may be preprogrammed into the control unit CU. New automatic and semiautomatic controls may be programmed by the operator 5 or the operator 5 may download preprogrammed or preconfigured automatic or semiautomatic controls, for example as a data packet, from a cloud service where the earthmoving machine E or the user has access to. The user may, for example, log into his or her user account or identify himself or herself using any known method into the earthmoving machine E or into the cloud service or the user may log or identify the earthmoving machine E into the cloud service and select the data packets he or she desires and has access to and download them. Data packets may be downloaded in every other known way, as well. Preferably, a user with administrator privileges may download the data packets the operator 5 requested.

For example, for unexperienced operator 5 it might be preferable to limit the maximum speed of the driving in work site as well as the motion controls of the earthmoving machine E. Preferably, controls may have some other limitations or prerequisites to function such as whether the controllers CO are attached or detached, and whether detached, regarding the location of the controllers CO. For example, if the controllers CO are too far, the control system CS may disable the controllers CO and if the controllers CO are too near, the control system CS may slow down the motions.

Preferably, the control system CS may be set to detect automatically or manually, in addition to the location of the operator 5, the direction or orientation of the operator 5 with respect to the direction or orientation and location of the earthmoving machine E, the boom 2 or the tool 3 and change the controls with respect to these directions or orientations. For example, when the operator 5 is outside the cabin facing the earthmoving machine E and the boom 2, controlling the tool 3 to go left as seen by the operator 5, the tool 3 may go left as seen by the side of the operator 5 and to right as seen by the side of the earthmoving machine E.

Figure 2 discloses an operator 5 controlling an earthmoving machine E from outside the cabin 4. The operator 5 has a vest where the controllers CO are attached and a headset 18 provided with one or two head-mounted display units 6 depicted in figure 5. The head-mounted display with the controllers CO enables the operator 5 to operate the control system CS outside the cabin 4 like using the control system CS inside the cabin 4. Both the controllers CO and the headset 18

communicate with one or more control units CU through one or more communication channel 19. The headset 18 may be used inside the cabin 4, as well. When using the headset 18 inside the cabin 4, the displaying means in the cabin 4 may be switched off if desired.

According to an embodiment, an operator selects to use only two controllers CO for controlling the operations of the earthmoving machine E. In the embodiment, the operator 5 is well experienced to use them so the operator 5 may detach the controllers CO and step outside the cabin 4 and continue, for example, after 5 second delay or one meter away from the earthmoving machine E, controlling the earthmoving machine E outside the cabin 4 with otherwise full control, but, when driving the earthmoving machine E outside the cabin 4, the maximum speed is limited to 0,5 km/h, for example.

According to an embodiment, the control system CS comprises two controllers CO.

According to an embodiment, an operator 5 has another set of controllers CO that the operator 5 uses when operating with detached controllers CO. Thus, the operator 5 need not to detach those controllers CO that are attached in the cabin 4.

According to an embodiment, the sets of controllers CO each have a selector, for example a switch or a button or the like, to select whether the set of controllers CO is operating or not operating. If more than one set of controllers CO is at the same time set to “operating” the certain earthmoving machine E, the closest set to the earthmoving machine overrides the other sets. This means that if attached set of controllers CO is set to “operating”, it overrides the others and if the attached set is set to “not operating”, the control system CS of the earthmoving machine E determines which of the controllers CO set to “operating” is the closest to the earthmoving machine E and lets the closest to operate and disables the others. If there is two sets equidistant to the earthmoving machine E set to “operating”, the control system CS may disable one or both and somehow signal that too more sets of controllers CO is set to “operating” mode.

According to an embodiment, the set of controllers CO operating the earthmoving machine E may operate the earthmoving machine E over the Internet or other suitable connection such that the operator 5 need not be within sight to the earthmoving machine E. These solutions may be suitable for mining purposes, for example. Thus, the operator 5 may operate the earthmoving machine E from outside the mine, for example. According to the embodiment, the operator 5

may have an additional visual connection (not shown) to the tool 3, surroundings of the earthmoving machine E or both via one or more video cameras (not shown) attached at suitable places in the earthmoving machine E such as carrier 1, cabin 4, boom 2 or tool 3.

The level of experience, or the skill level, may be set to the control system CS manually by, for example, the operator 5 or the user with administrator privileges. The skill level may be set also by the control system CS itself, for example, by analyzing all the time the selections and controls given by the operator 5 or by retriving the history data gathered from the operator 5, meaning the user logged in, regarding the selections and controls given by the user or both. History data may have been gathered both from the earthmoving machine E, from similar earthmoving machine, from any other earthmoving machine, from any other similar machine and a simulator simulating some or any of the previously mentioned.

Analyzing selections and controls may contain, for example, data about how fast the user makes selections in between different menu items or jumps from one menu to the other or how quick or smooth the controls are in controlling, for example, driving system, peripheral devices, maintenance system, road navigation system, work site navigation system, positioning the earthmoving tool 3 with respect to the work site, weighing system, automation system, measuring system and process control.

According to an embodiment, the skill level may be different regarding what is been controlled, such that one operator, or user, may have high skill level in controlling the tool 3 and the other may have high skill level in using the driving system and so on.

The data regarding each user, or operator, may contain information of each user's experience regarding various earthmoving machines E and may be at least one of gathered, uploaded and downloaded by the earthmoving machine E, uploaded and downloaded by the user and the operator and uploaded and downloaded by the user with administrator privileges. Here uploading means transmitting the gathered data from the control system CS to the cloud service or identity card or the like and downloading means retrieving the history data or skill level data from the cloud service or identity card or the like to the control system CS. Each earthmoving machine E may monitor the usage of the controllers CO in each situation, analyze it, gather it and upload it. The user with administrator privileges or the user himself or herself may insert the data according to his knowledge of

the user's experience regarding to each kind of earthmoving machine E, for example, according to a test or an examination performed or passed.

The limitation, for example, to the maximum speed may be set by the supervisor of the work site, by the operator 5 himself or by the control system CS that has the data of the controlling hours outside the cabin operated by the operator 5. When controlling the earthmoving machine E outside the cabin 4, the head-mounted display units 6 or the like or any other display unit 6 is not mandatory. Using the controllers CO without seeing any display unit 6 does not necessarily restrict the current use of the earthmoving machine E, if the user remembers the selections needed without seeing them on any display.

According to an embodiment, when the sensors sensing the surroundings of the tool 3 detect that the operator is in only one meter distance from the tool 3, the control system CS restricts the motion speeds of the earthmoving machine E, the boom 2 and the tool 3 to, for example, 20% of the motion speeds set in unrestricted conditions to the operator 5.

Figure 3 show feasible earthmoving machines. Regarding the earthmoving machine and the habits of the user, the number of the controllers CO may vary. Optimal amount of controllers CO in excavator is two. Also the amount of the controllers CO may be one, three or four. If the amount is three or four, one or two of them may be usable by feet, for example. Not all the controllers CO need be detachable. If only part of the controllers CO were detached, the operation mode of each controller CO may change, since the controllers CO not detached may be disabled and the features of the disabled controllers CO may be added to the controllers CO detached. Preferably the control system CS requests user action whether to change the operation mode or not.

Figure 4a discloses a separate transparent display unit 6 or combiner arranged at a distance from a windscreen 10. Figure 4b discloses a solution wherein a combiner 6 is fastened to an inner surface of the windscreen 10. Figure 4c discloses an integrated solution wherein the transparent display unit 6 is located inside a structure of the windscreen 10.

Figure 5 discloses a headset 18 or media glasses provided with one or more transparent display units 6. The headset 18 may communicate with one or more external or internal control units CU through one or more data communication 19. The same applies also for a helmet 20, depicted in figure 6, which is also provided with the transparent display units 6. In both arrangements the earthmoving images and data elements may be displayed so that they appear to locate

at a visual distance from the transparent display units 6, which are located close to eyes of the operator.

It will be obvious to a person skilled in the art that, as the technology advances, the inventive concept can be implemented in various ways. The invention and its embodiments are not limited to the examples described above but may vary within the scope of the claims.

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Claims

1. A multi-modal control system (CS) for controlling an earthmoving machine (E), the control system (CS) comprising:

one to four controllers (CO) and at least one control unit (CU),

the control system (CS) further comprising at least one displaying means for displaying controls selectable and controllable by the one to four controllers (CO), **characterized** in that:

the at least one control unit (CU) is configured to receive selections and controls from the one to four controllers (CO) for controlling all the operations of the earthmoving machine (E) controllable by the one to four controllers (CO);

the one to four controllers (CO) are operable both attached and detached; and

the control system (CS) futher comprises means for determining the location of each of the one to four controllers (CO) with respect to the earthmoving machine (E).

2. The multi-modal control system (CS) according to claim 1, **characterized** in that the operation mode of the one to four controllers (CO) depends on whether each of the one to four controllers are attached or detached.

3. The multi-modal control system (CS) according to claim 1 or 2, **characterized** in that the operation mode of each of the one to four controllers (CO), when detached, depends on the distance between these controllers (CO) and the earthmoving machine (E).

4. The multi-modal control system (CS) as claimed in any one of the preceeding claims, **characterized** in that the operation mode of each of the one to four controllers (CO), when detached, depends on the distance between these controllers (CO) and the earthmoving tool (3) of the earthmoving machine (E).

5. The multi-modal control system (CS) as claimed in any one of the preceeding claims, **characterized** in that the operation mode of each of the one to four controllers (CO), when detached, depends on the distance between each other.

6. The multi-modal control system (CS) as claimed in any one of the preceeding claims, **characterized** in that the operation mode of the one to four controllers (CO) depends on the distance between a detected obstacle and the earthmoving tool (3) or the earthmoving machine (E).

7. The multi-modal control system (CS) as claimed in any one of the preceeding claims, **characterized** in that the operation mode of the one to four controllers (CO) depends on the user specified adjustments made by or made for the user currently logged in to the control system (CS).

8. The multi-modal control system (CS) as claimed in claim 7, **characterized** in that the extent of the available adjustments depends on the skill level data of the user currently logged in, the skill level data being defined by at least one of: usage hours of the earthmoving machine (E), usage hours of the respective earthmoving machine (E), competence level accomplished or passed by an examination or test.

9. The multi-modal control system (CS) as claimed in any one of the preceeding claims, **characterized** in that the operation of the earthmoving machine (E) controllable by the one to four controllers (CO) is at least one of: driving system, peripheral device, maintenance system, road navigation system, work site navigation system, positioning the earthmoving tool (3) with respect to the work site, weighing system, automation system, measuring system and process control.

10. The multi-modal control system (CS) as claimed in any one of the preceeding claims, **characterized** in that the control system (CS) gives feedback by at least one of the following signals: graphical, augmented reality, virtual reality, audiovisual, visual illumination, haptics and force-feedback.

11. The multi-modal control system (CS) as claimed in any one of the preceeding claims, **characterized** in that the user with administrator privileges define the skill level by editing the skill level data of the user.

12. The multi-modal control system (CS) as claimed in any one of the preceeding claims, **characterized** in that the user with administrator privileges define the skill level by editing the skill level data of the user in a cloud service and the earthmoving machine (E) retrieves the data from the cloud service.

13. The multi-modal control system (CS) as claimed in any one of the preceeding claims, **characterized** in that the at least one control unit (CU) is configured to receive selections and controls from the one to four controllers (CO) for controlling at least the tool 3 and the driving of the earthmoving machine (E).

14. The multi-modal control system (CS) as claimed in any one of the preceeding claims, **characterized** in that the at least one control unit (CU) is configured to receive selections and controls from the one to four controllers (CO) for controlling all the operations of the earthmoving machine (E) controllable by the operator of the earthmoving machine (E).

15. The multi-modal control system (CS) as claimed in any one of the preceeding claims, **characterized** in that the amount of controllers (CO) is two.

16. An earthmoving machine (E), the earthmoving machine (E) comprising:

a movable carrier (1);

at least one earthmoving tool (3);

peripheral devices;

actuating means for moving the earthmoving tool (3) in relation to the carrier (1) and means for controlling the peripheral devices;

a control system (CS) comprising control unit (CU) for controlling the operations of the earthmoving machine (E);

and comprising sensing means (11, 12) for providing the unit with position data of the earthmoving tool (3) and the carrier (1);

and wherein the control system (CS) comprises at least one displaying means and one to four controllers (CO) for controlling the operations of the earthmoving machine (E), **characterized** in that the at least one control unit (CU) is configured to receive selections and controls from the one to four controllers (CO) for controlling all the operations of the earthmoving machine (E) controllable by the one to four controllers (CO);

the one to four controllers (CO) are operable both attached and detached; and

the control system (CS) futher comprises means for determining the location of each of the one to four controllers (CO) with respect to the earthmoving machine (E).

17. The earthmoving machine (E) as claimed in claim 16, **characterized** in that the earthmoving machine (E) is one of the following: excavator, bulldozer, motor grader, compaction machine, piling machine, deep stabilization machine, surface top drilling machine.

18. A method for controlling an earthmoving machine (E), **characterized** in that the method comprises:

determining the operation mode of the at least one controller (CO)

by determining whether the at least one controller (CO) is attached or detached and

by determining the location of the at least one controller (CO);

selecting, in the determined operation mode, the operation to control from the selectable and controllable controls containing all the operations of the earthmoving machine (E) controllable by the at least one controller (CO) and

controlling the selected operation of the earthmoving machine (E).

19. A computer program product comprising executable code that when executed, cause execution of functions according to any one of claims 1-18.

20. A computer program embodied on a non-transitory computer readable storage medium, the computer program being configured to control a processor to execute functions according to any one of claims from 1 to 18.

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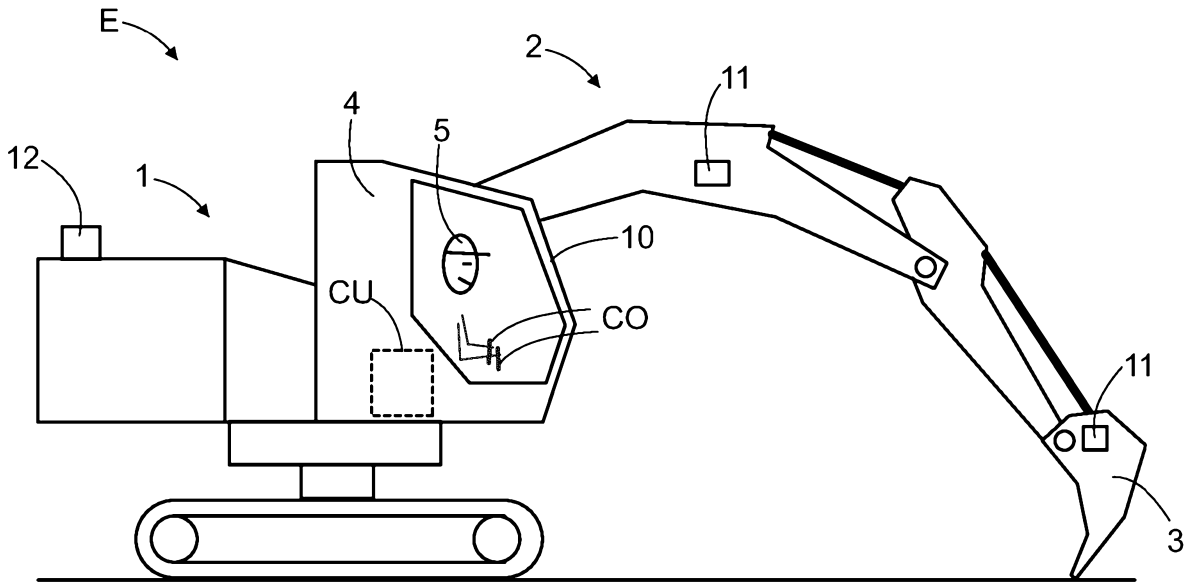

FIG. 1

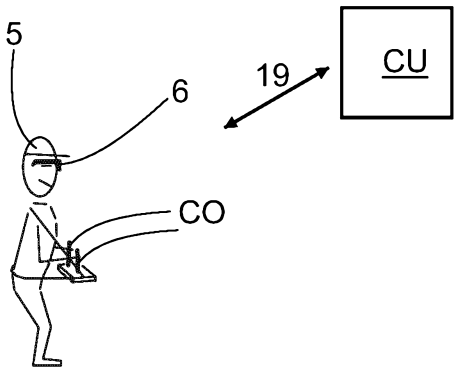

FIG. 2

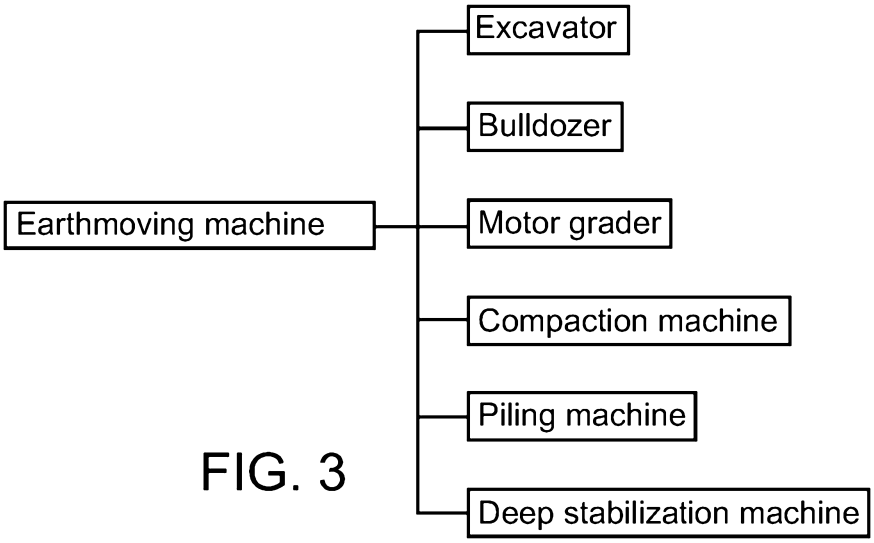

FIG. 3

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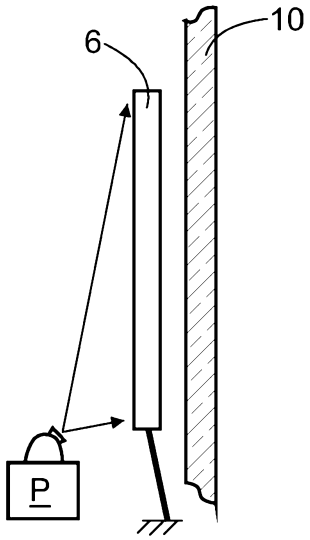

FIG. 4a

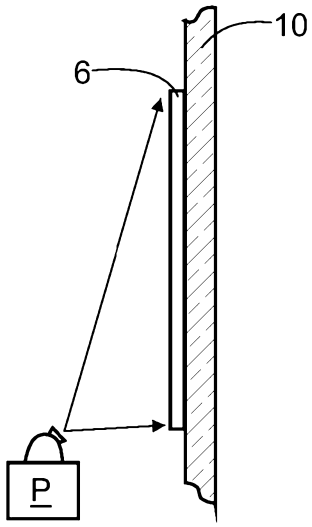

FIG. 4b

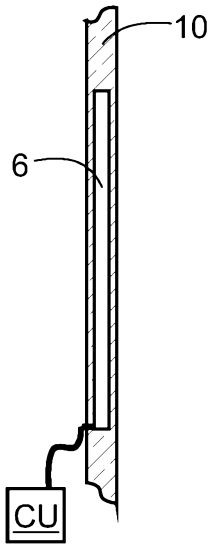

FIG. 4c

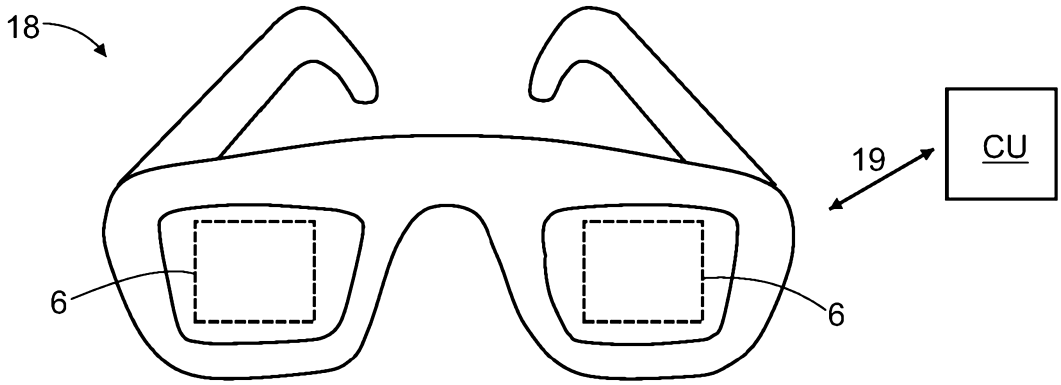

FIG. 5

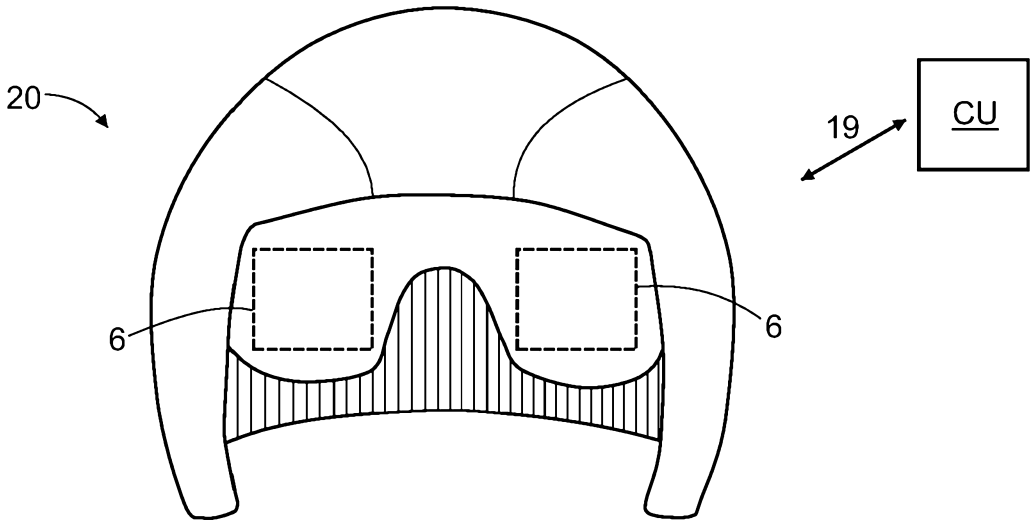

FIG. 6