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(54) **LEVELLING DIAGNOSTIC SYSTEM**

(57) Method for evaluating of a quality of a generated pavement or a generated surface, generated by use of a construction machine, especially a road construction machine, road finishing machine or milling machine, comprising the following steps: receiving sensor values from one or more sensors and/or a sensor system of the construction machine; determining a specific sensor value combination within the sensor values, the specific sensor value combination being assigned to a specific quality situation; and outputting an operator message dependent on the specific quality situation.

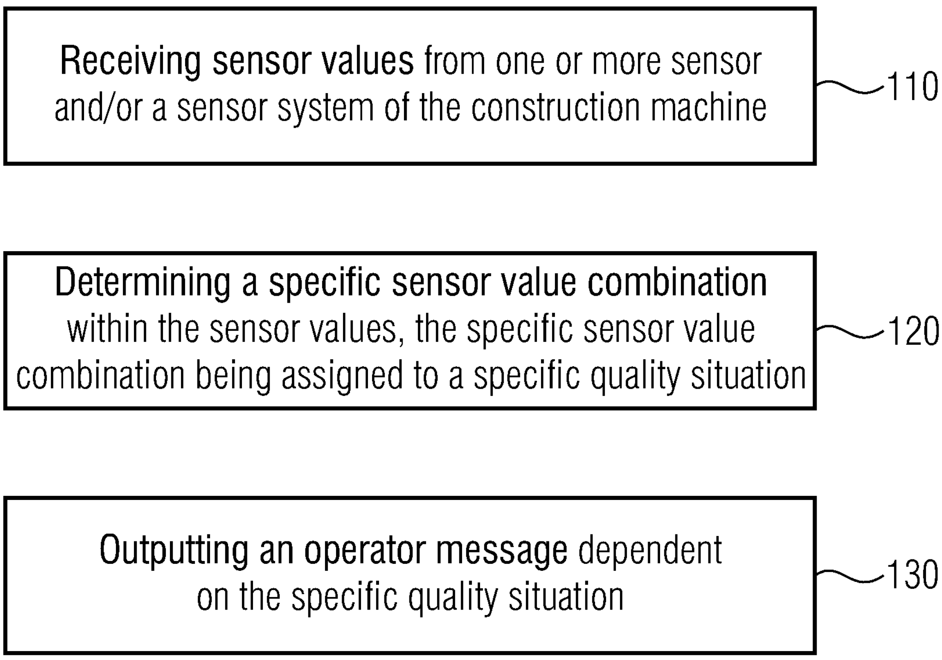

Fig. 1a

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Description

[0001] Embodiments of the present invention refer to a method for (real time) evaluating of a quality of a generated pavement (paving quality) or a generated surface. Further embodiments refer to a diagnosis control unit, to a process control unit comprising a diagnosis control unit and to a construction machine, especially a road construction machine like a paving machine or milling machine, comprising a diagnosis control unit and/or process control unit. In general, embodiments of the present invention refer to mobile construction machines, in particular, to levelling systems for road construction machines (road paver, asphalt paver) or milling machines.

[0002] In general, a road paver on a tracked or wheeled drive runs on a prepared foundation (road bed) onto which a street surface to be produced or road pavement to be produced is to be applied. As a rule, the road pavement is a bituminous material, wherein however layers with sand or stone or concrete layers may also be added in. Provided behind the road paver, in the direction of travel, is a height-adjustable screed, and piled on its front side is a supply of the road paving material that is supplied and distributed by a conveyor device that makes sure that the amount of road paving material kept on the front side of the screed is adequate but is not too much. The height of the rear edge of the screed relative to the surface of the prepared foundation, which may also be formed by an old road pavement covering, establishes the thickness of the street surface produced prior to its subsequent further consolidation by rollers. The screed is held on a tow arm that is borne rotatably movable about a tow point arranged in the center area of the road paver, the height of the screed being determined by a hydraulic adjusting device. The height of the screed is controlled by at least one levelling system.

[0003] Mobile milling machines, which are also referred to as so-called cold milling machines, comprise a rotatably mounted milling drum that is fixed with respect to its axis of rotation relative to the chassis of the milling machine. The milling machine has a front and a rear landing gear. Depending on the milling machine or milling machine type, one of the two landing gears (front or rear) can be manually adjusted to a fixed value in height. The corresponding other landing gear has a chassis height adjustment, which is controlled in response to a milling (cutting) depth control signal.

[0004] According to the prior art, there are some approaches helping an operator to achieve a good result by paving or when milling using a paver or road milling machine.

[0005] A known road paver (road finisher) is described for instance in EP 0 542 297 A1. The road finisher has, instead of a mechanical sensing runner for producing a level-control signal for a vertically adjustable plate, an ultrasonic control device with at least two, preferably three, ultrasonic sensors which are arranged in the direction of movement of the road finisher at a considerable distance on the plate. By means of the ultrasonic sensor signals, the distances of each ultrasonic sensor from a reference surface are detected, those values which lie outside the plane by more than a predetermined distance, which plane is determined by the measurement points assigned to the remaining distances, being rejected as incorrect measurements. The evaluation device calculates the projected level at the rear edge of the plate with reference to the level signals, the mutual spacings between the sensors and the distance of a sensor from the rear edge of the plate.

[0006] Furthermore, EP 0 547 378 A1 describes an apparatus for controlling the cutting depth of a road milling machine by vertical adjustment of both the front and rear travelling gear on the basis of a milling depth control signal, which is generated by a tracer ski by sampling a reference plane, including at least three ultrasonic sensors arranged one behind the other in the direction of movement of the milling machine, and an evaluation means for determining the distances between the ultrasonic sensors and a reference plane to derive therefrom an inclination signal as well as an averaged distance signal. The evaluation means controls the height of the two travelling gears such that the average distance of the milling drum as well as the position of the machine relative to the reference plane are adjusted.

[0007] The EP 3 795 748 A1 describes a levelling system for a road construction machine, especially for a paving machine or a road milling machine. The levelling system comprises a first height sensor arrangement, a second height sensor arrangement, a first controller, a second controller and an additional sensor.

[0008] However, all of the above-discussed approaches do not enable to directly improve the quality of the produced surface/pavement.

[0009] An objective of the present invention is to provide a concept enabling an improved tradeoff between usability, generated quality and compatibility to already used systems.

[0010] The objective is solved by the subject-matter of the independent claims.

[0011] Embodiments of the present invention provide a method for (real time) evaluating of a quality of a generated pavement or a generated surface, generated by use of a construction machine, especially a road construction machine, like a road finisher or milling machine. The method comprises the basic steps:

- Receiving sensor values from one or more sensors, e.g., height sensors and/or a sensor system (like a levelling system) of the construction machine;
- Determining a specific value combination within the sensor values. For example, the specific sensor value combination can comprise two sensing values of two (different) sensors or (ultra)sound sensors of the sensor system. Alternatively, the specific sensor value combination can (according to further embodiments) comprise some sensor values received over

the time, i.e., belonging to different points of time. The specific sensor value combination is assigned to a specific quality situation. This means that some sensor values in combination can indicate a specific quality;

- Outputting an operator message dependent on the specific quality situation, e.g., how to improve the recent quality situation.

[0012] Embodiments of the present invention are based on the finding that sensor values or also other values, like control parameters may have a specific pattern which is related to a specific problem. These known patterns that are related to specific problems can be recognized by a kind of diagnostic method or diagnostic system. Thus, embodiments of the present application expend a levelling system for road finishing machine or milling machine by a levelling diagnostic system that monitors and records control loop parameters of the levelling system to recognize the known patterns. According to embodiments, the levelling diagnostic system, only seeing the levelling system inputs (sensor inputs) and outputs (actuators, valves, ...) see patterns that could be recognized and diagnosed without a person. Starting from such a diagnosed specific quality situation, a hint for an operator or a general operation message can be output so that the levelling diagnostic system is artificially trouble shooting the levelling system control loop and communicates automatically to the operator what is wrong and which adjustment should be done.

[0013] Another embodiment provides a diagnosis control unit, which can be part of a process control unit or a separate part. According to embodiments, the diagnosis control unit can be implemented into an external entity, like a smart device (tablet, PC, smartphone, etc.). The diagnosis control unit comprises three entities, namely an (input) interface for receiving sensor values, a processor for determining a sensor value combination (assigned to a specific quality situation) and an (output) interface for outputting an operator message dependent on the determined quality situation.

[0014] According to further embodiments, the specific value combination is out of a plurality of specific value combinations. For example, the plurality of specific sensor value combinations may be stored by a database. According to further embodiments, a plurality of specific sensor value combinations comprise another specific sensor value combination being assigned to another specific quality situation, such that another operator message can be output dependent on another specific quality situation. The plurality of specific value combinations enables to recognize different patterns. Here, it should be noted that the different combinations may be stored internally within a database or by an external database which may have the advantage that this database can be enhanced, so that a plurality of diagnosis control units can participate on the newly added recognizable patterns. According to embodiments, the operator message can comprise an information regarding the specific quality information and/or a suggestion for how to improve the specific quality situation, for example, an information on a parameter to be adapted or an actuator value to be adapted so as to improve the current quality situation.

[0015] As discussed above, not only one sensor value to a first point of time is taken into account, but a plurality of sensor values belonging to a plurality of points of time. Thus, according to embodiments, the sensor values are received over time, wherein the sensor value combination is determined taking into account value deviations of sensor values received over the time of at least one sensor value of the sensor values.

[0016] According to further embodiments, the method may additionally comprise the step of receiving one or more actuator values or one or more process control parameters, wherein the step of determining is performed taking into account the one or more actuator values and/or the one or more process control parameters. This means that according to further embodiments, the sensor value combination indicating a specific quality situation is determined not only based on sensor values, but also based on actuator values or process control parameters. According to embodiments, one sensor value of the sensor values or all sensor values and/or an actuator value is received from a levelling system of the construction machine. According to further embodiments, the sensor value of one sensor value of the sensor values may be a sensor value of a distance sensor, a cross slope sensor, or a 3D process control system. Coming back to the actuator value(s) /process control parameter(s): According to embodiments, an actuator value of the one or more actuator values describes a height position of a tool like the screed or a width information of the tool/screed, a speed information of the construction machine, etc. According to embodiments, the process control parameter may comprise a temperature information and/or a material temperature information, e.g., of the paving and/or an RPM information, e.g., of the milling drum.

[0017] According to embodiments, all the above-mentioned values, e.g., the sensor values, are available at the CAN bus. Therefore, a sensor value of the sensor values or an actuator value and/or a process control parameter are extracted from a CAN bus. The diagnosis control unit may therefore comprise an interface for receiving sensor values, which is implemented as a CAN bus.

[0018] According to further embodiments, the diagnosis control unit may comprise an interface outputting an operation message, wherein this interface may be realized as human machine interface (HMI), like touch display. The diagnosis control unit can (additionally or as an alternative) comprise an interface outputting an operating message, this interface may be realized as a wireless communication link to a mobile device, like a smartphone, Tablet-PC or the like. The wireless communication link can be, for example, a Bluetooth or WLAN connection or the like. According to further embodiments, the diagnosis control unit comprises an internal database or an interface for generating access to a database, e.g., over the air, wherein the database during a plurality of specific sensor value combinations.

[0019] Another embodiment provides a process control unit or smart device comprising a diagnosis control unit. Another embodiment provides a construction machine, especially a road construction machine, like a paving machine or milling machine comprising a diagnosis control unit or a process control unit/smart device having the diagnosis control unit integrated.

[0020] With respect to the above-discussed embodiments, it should be noted that the sensor value combination may just comprise sensor values or may additionally comprise actual values and/or process control parameters. Thus, a sensor value combination may be defined by some sensor values in combination with one or more actuator values and/or in combination with one or more process parameters. For example, the process parameter may be a temperature information for the paving material, wherein the sensor values determined over the time indicate a kind of wave of the generated pavement. One actuator value indicates that the current adaption rate of the height of the screed is quite low, so that it can be concluded that an increased adaption rate of the height position would improve the evenness of the pavement. Thus, any information to the operator can be output giving the hint to increase the adaption rate. The correct adaption rate may further be dependent on the current pavement temperature, so that the output message may vary dependent on the respective process control parameter.

[0021] In another example, the measured value of one or more sensors (like a distance or a slope sensor) has exceeded or fallen below the permissible measuring range or the control deviation of one or more sensors is greater than the set control window. In this way, any information can be output to the operator, indicating that the sensor or sensors should be realigned on the reference (rope, curb, milling edge, etc.).

[0022] In this context, it can also be established, for example, that one or more sensors are sending inadmissible or contradicting messages or measured values. Thus, any information can be output to the operator that indicates that the electrical (plug) connection of the faulty sensor(s) must first be released, the sensor(s) newly realigned on the reference and then plug it in again.

[0023] In another example, which relates to a laser receiver as a sensor, the laser receiver receives several signals from a laser transmitter (e.g. a rotary laser) due to reflections in its surroundings. This can be caused by reflective surfaces (e.g. car glazing, windows, etc.) in the area of influence of the laser beam. In this way, any information can be output to the operator, which indicates that the laser transmitter is to be covered up to the really required section of a circle, or to cover the reflective surfaces.

[0024] Furthermore, another example relates to a control loop behavior of a paver screed. Due to a mismatch of the control parameters to the hydraulic system, the screed oscillates when paving material is paved, i.e. the tow point changes constantly (up and down) and the tool (screed) also goes up and down. A bumpy road is built, which is not wanted. These up and down movements can, for example, be recorded using sensor values and actuator activities. At this point, any information can be output to the operator in order to change the parameter settings of the hydraulic system, for example the setting of the dead band with a proportional controller or the so-called Min.-Pulses and/or Max.-Pulses when raising and lowering the tow point when a two-position controller (black / white controller) is used. This reduces the travel of the tow point cylinder when adjusting (leveling) the screed.

[0025] According to a further example, a mismatch of control parameters to the hydraulic system in a road milling machine would result in short-wave or long-wave unevenness when milling the road surface material. If the lifting cylinders are moved too fast or too far to regulate the milling depth, this leads to constant up and down movements (swinging) of the milling drum and thus to short-wave bumps in the milled road surface. In contrast, a change in the lifting cylinder position that is too small would mean that the milling depth cannot be corrected sufficiently. This is where long-wave bumps usually arise, which are also not desired. In this way, any information can be output to the operator, to change the parameter settings of the hydraulic system, for example the so-called Min.-Current and/or Max.-Current when raising and lowering the lifting cylinders.

[0026] Below, embodiments of the present invention will subsequently be discussed referring to the enclosed figures wherein:

Fig. 1a shows a schematic flow diagram of a basic method according to embodiments;

Fig. 1b shows a schematic block diagram of a diagnosis control unit according to a basic embodiment;

Fig. 1c shows a schematic block diagram of a diagnosis control unit according to enhanced embodiments;

Fig. 1d shows a schematic block diagram of a diagnosis control unit according to another enhanced embodiment;

Fig. 2 shows a schematic block diagram of a construction machine/paving machine according to embodiments;

Fig. 3 shows another block diagram of a paving machine according to further embodiments;

Fig. 4 schematically illustrates a levelling system, e.g., belonging to a paving machine according to embodiments;

Fig. 5 shows a schematic block diagram of a paving machine according to enhanced embodiments including optional features; and

Fig. 6 shows a schematic block diagram of a construction machine/milling machine according to embodiments.

[0027] Below, embodiments of the present invention will subsequently be discussed referring to the enclosed figures, wherein identical reference numerals are provided to objects having similar or identical functions, so that the description thereof is mutually applicable and interchangeable.

[0028] Fig. 1 shows a method 100 comprising three basic steps 110, 120, and 130, which will be discussed taking reference to Fig. 1b.

[0029] Fig. 1b shows a construction machine 10, here a paving machine/road finishing machine comprising a measurement system. The measurement system may be a levelling system, which comprises at least the one sensor 41. The sensor system or the one sensor 41 receives measurement values M1, M2, M3, etc. These measurement values can be, for example, measured values for subsequent points of time, or measurement values of different sensors or measurement points. The measurement values M1, M2, M3, ... can be received by the diagnosis control unit, e.g., a levelling diagnostic system, which is marked by the reference numeral 300. Within Fig. 1a, this step is marked by the reference numeral 110 "receiving sensor values" from one or more sensors 41 and/or sensor system 41 of the construction machine 10.

[0030] The diagnosis control unit 300 processes these sensor signals M1, M2, and M3 so as to determine a pattern within the sensor signals. In the table illustrated by Fig. 1b, the patterns P1 and P2, also referred to as sensor value combinations within the sensor values M1, M2, M3, ... are illustrated. The step of determining a pattern or determining a specific sensor value combination is marked by the reference numeral 120 in Fig. 1a. As can be seen, the two patterns P1 and P2 use the same sensor values M1, M2, M3, wherein each pattern P1 and P2 is defined by a different combination of the values. For example, the value combination for pattern P1 is 2-4-3 for the three sensors M1, M2, M3, while the value combination for pattern P2 is 3-3-3. This enables the diagnosis control unit 300 to determine the pattern P1, if the sensor system 41 delivers the sensor signals 2-4-3 and the pattern P2, if the sensor system 41 delivers the sensor signals 3-3-3.

[0031] For example, each pattern may be assigned to a specific quality situation of the generated surface/generated pattern 22. The quality of a pavement 22 assigned to pattern 2 may be high, e.g., an even surface, while the quality of the pavement 22 assigned to pattern P1 may be lower, e.g., an uneven surface. Thus, a sensor value combination 3-3-3 indicates a high quality, while sensor value combination 2-4-3 indicates a low quality. At this point it should be noted that these are only examples of sensor value combinations and patterns. Other combinations and patterns are also conceivable.

[0032] In case pattern P1 is determined by the diagnosis control unit 300, an operator message may be output, e.g., using a human machine interface like a display. This operator message may include an information on the generated quality or even instructions for how to improve the quality, such that the operator can adapt the process. In Fig. 1a, this step is illustrated by the reference numeral 130. In view of this method step 130, it becomes clear that the operator message is (generally speaking) dependent on the specific quality situation determined by use of the patterns 120.

[0033] To sum up, the idea is to identify specific situations or problems that can be detected in real time in observed patterns P1 and P2 in the levelling system control loop or another measurement system. This enables to communicate recommended corrective actions to the operators, or screed operators, and/or to the road construction company.

[0034] The levelling diagnostic system 300 can proactively identify problems and then notify the screed operators on what should be corrected. This helps to make the leveling system smarter with some logic or intelligence for self-diagnostics. According to embodiments, the above-discussed diagnosis control unit may be integrated into a process control unit and/or connected to a process control unit or integrated into the levelling system or connected to the levelling system. By collecting data and screening them, a pattern should be found on the output to get information on how to solve a problem that had been identified. Furthermore, if the screed operators can be removed from the paver for semi-autonomous operation, this functionality would be very helpful. The diagnosis control unit/levelling diagnostic system forms the basis for such a semi-autonomous operation where the levelling diagnostic system then acts as a virtual expert instead of the existing experts in the field.

[0035] According to one example, incorrect parameter settings can be illustrated. If the sensitivity settings, working window, or valve settings are too high or too low, it is obvious to a trained person watching that there is a problem with the settings. Therefore, according to further embodiments, the diagnosis control unit 300 may be access to actuator values, e.g., the actuator value defining the high position of the screed or to process parameters, e.g., having a temperature or a velocity of the paving machine. An actuator value is a value belonging to the levelling system itself, while an operation parameter is an external parameter, e.g., of the construction machine 10 or a parameter defined by the circumstances. For example, a process parameter can also be a measured parameters like the temperature value. Further, the known problems are: sensor out of range, hydraulic problems, wrong valve settings, incorrect levelling system control loop parameter settings or the use of a wrong sensor. In such a case, the sensor value may generally interpreted as an information received from the measurement system.

[0036] It is foreseen as a levelling diagnostic system that only has a window into the levelling system controller or levelling control somehow. Thus, the levelling system controller or the levelling kernel may comprise the diagnostic control unit 300 or may comprise a processor for performing the method 100. Possibly, it is a software product (app) that interfaces with the levelling system to monitor and self-diagnose levelling system problems. In such a case, the processor may be implemented into the smart device, like a tablet PC having access to at least sensor values or even to actuator values and/or process parameters, wherein the method 100 is performed by the processor of the smart device. Part of this could be simply remoted diagnostics.

[0037] According to embodiments, the different patterns P1 and P2 are stored by a database. For example, the database may be an internal database of the diagnostic control unit 300 or an external database, e.g., a cloud based database.

[0038] Below, the diagnostic control unit 300 may be discussed in the context of a road finishing machine/paver 10.

[0039] Fig. 1c and 1d show a levelling system (measurement system/sensor system) 40 for a road finishing machine (paver) 10 or a road milling machine. The levelling system 40 comprises a levelling system control unit 45, consisting essentially of a process control unit 45A and an operating and monitoring unit (control and display device) 45B. The process control unit 45A reads in and processes measured sensor values and controls, using the example of a road finishing machine (paver) 10, the height position of a paver screed 15 (not shown in Fig. 1c and 1d) as a function of the measured sensor values, that means the process control unit 45A functions as a levelling unit. Via the operating and monitoring unit 45B, an operator, for example the paver screed personnel, can set adjustments or changes to various parameters concerning the levelling or monitor them during the working process. The operating and monitoring unit 45B serves as a so-called human-machine interface (HMI or MMI). In a preferred variant, the process control unit 45A and the operating and monitoring device 45B are combined in one device or in one housing, that means components are integrated within one device or housing.

[0040] Furthermore, the levelling system 40 comprises at least one sensor 41 connected to the process control unit 45A, whereby it is also conceivable that the levelling system 40 comprises more than one sensor, all of which are connected to the process control unit 45A. As shown in Fig. 1c and 1d, the levelling system 40 comprises as an example two distance sensors 41 and 44, and an additional sensor 200, which can be for instance a slope sensor, a 3D sensor system, or the like. The illustration is only an example and the levelling system 40 can also include further known sensors or known sensor systems (not shown and mentioned here).

[0041] All sensors of the levelling system 40 may be preferably connected via cable connections to the process control unit 45A, for instance via a CAN fieldbus system (CAN INPUT) or other kind of known network or known fieldbus system used in mobile construction machines. The sensors can also be separately (and directly) connected to the process control unit 45A, that means via an individual or single cable connection for each sensor or connected to the process control unit 45A via a kind of hub, distribution (junction) box or the like. Note, the above-discussed entities are partially optional. For example, the process control unit 45a can be without the operating and monitoring unit 45b. Furthermore, different sensors or sensor systems may be used.

[0042] According to further embodiments, the levelling system 40 consists of at least one actuator 51 connected to the process control unit 45A, whereby it is also conceivable that the levelling system 40 comprises more than one actuator, all of which are connected to the process control unit 45A. As shown in Fig. 1c and 1d, the levelling system 40 comprises as an example two actuators 51 and 52, which can be for instance one or more hydraulic valves or hydraulic valve control system(s) or the like. Actuators 51 and/or 52 are for instance used to extend and retract tow arm cylinders of a road finishing machine (paver) 10, or to extend and retract front and rear landing gear cylinders 16F/R of a road milling machine 10.

[0043] All actuators of the levelling system 40 are preferably connected via cable connections to the process control unit 45A, for instance via a CAN fieldbus system (CAN OUTPUT) or other kind of known network or known fieldbus system used in mobile construction machines. The actuators can also be separately (and directly) connected to the process control unit 45A, that means via an individual or single cable connection for each actuator or connected to the process control unit 45A via a kind of hub, distribution (junction) box or the like.

[0044] According to further embodiments, the process control unit 45A can be connected to a machine control system of the road finishing machine (paver) 10 or the road milling machine 10, for instance via the CAN fieldbus systems (CAN INPUT and/or CAN OUTPUT) or another individual CAN fieldbus system, in order to get further data of the machine 10 or of the working process (machine speed, machine status, ...) or in order to provide data to the machine 10 or to the working process (sensor data, levelling parameters, ...). It is also conceivable, that the connection between the machine control system of the road finishing machine (paver) 10 or the road milling machine 10 is another individual or single cable connection or a wireless connection.

[0045] According to embodiments, a levelling diagnostic system 300 is connected to the levelling system 40 via connections 301, 302 and/or 303, as shown in Fig. 1c. The levelling diagnostic system 300 accesses sensor and actuator data (via connections 301 and 302) as well as data from the process control unit 45A (via connection 303). As already explained above for connections between sensors and actuators and the process control unit 45A, the individual connections 301, 302 and 303 themselves are either CAN fieldbus or other kind of known network or known fieldbus system connections or individual direct or single cable connections. The levelling diagnostic system 300 itself can be a non-depicted and not further defined levelling diagnostic unit (diagnosis control unit) with an appropriate diagnostic software, which can read in, process and output data. For example, the levelling diagnostic system 300 can read in sensor and actuator data via connections 301 and 302 and / or data from the process control unit 45A of the levelling system 40 via connection 303 to analyze parameter settings or the like and outputs information to the operator (via connection 303 to the operating and monitoring unit 45B) what is wrong and which adjustments have to be done. Furthermore, the diagnosis control unit may comprise an interface outputting an operation message, wherein this interface may be realized as human machine interface (HMI), like touch display. The diagnosis control unit can (additionally or as an alternative) comprise an interface outputting an operating message, this interface may be realized as a wireless communication link to a mobile device 80, like a smartphone, Tablet-PC or the like. The wireless communication link can be, for example, a Bluetooth or WLAN connection or the like. It is also conceivable, that the levelling diagnostic system 300 is a software product running also on the process control unit 45A. This means that in addition to the levelling software, there is also a diagnosis software on the process control unit 45A that monitors data of the inputs and outputs (sensor and actuator data) as well as the levelling data and outputs information to the machine operator. The operating message can then be shown, for example, as a text message and/or in the form of (animated) symbols or the like.

[0046] In another embodiment of the invention, as shown in Fig. 1d, the levelling diagnostic system 300 is a software product (App), running on a remote data server system 90 or on a mobile device 80, which can be, for example, a laptop computer or a tablet PC or a smartphone or the like. The mobile device 80 has a communication unit 85 to communicate via corresponding wireless connection types such as WLAN, Bluetooth, etc. The levelling diagnostic system 300 is connected to the levelling system 40 via a wireless connection. Therefore, the process control unit 45A of the levelling system 40 is connected via a cable connection 70k to a wireless communication interface unit 70. Via the wireless communication interface unit 70, the levelling system 40 (the process control unit 45A) can wirelessly exchange data with the levelling diagnostic system 300 on the remote data server system 90 and / or on the mobile device 80, that is to say to wirelessly transmitting data to said devices 80 and 90 and receiving data wirelessly from these devices 80 and 90. The levelling diagnostic system 300 can read in, process and output data of the levelling system 40. For example, the levelling diagnostic system 300 can read in sensor and actuator data and / or data from the process control unit 45A of the levelling system 40 and outputs information on the mobile device 80 to the machine operator or a construction site supervisor what is wrong and which adjustments have to be done, whereby it is conceivable to output the information also on the operating and monitoring unit 45B.

[0047] As a result, a machine operator or construction site supervisor always has an overview of the paving process and can react immediately in the event of problems.

[0048] Fig. 2 shows a road finishing machine 10 illustrated schematically in a side view, comprising a control platform 11, a material bunker 12 and a screed 15 as a tool, which is movable attached to the machine chassis via two tow arms 13R (right machine side) and 13L (left machine side, non-depicted). During the paving drive, the road finishing machine 10 moves on the underground to be asphalted 21, whereby paving material is transported from the material bunker 12 via a non-depicted conveyor device underneath the control platform 11 through the chassis of the road finishing machine 10 to the rear to the screed 15 by which it is processed into a new pavement layer 22.

[0049] The road finishing machine 10 comprises a levelling system 40 as described above, with at least the following entities, namely a distance sensor 41R as a single sensor and a levelling system control unit 45R, consisting essentially of a process control unit 45RA and an operating and monitoring unit (control and display device) 45RB as already described above. The distance sensor 41R (arranged at the right side of the screed 15) may be an ultrasonic sensor measuring a distance/height s1R to the underground 21, i.e., it measures a distance substantially perpendicular to the underground 21. The sensor 41R, the levelling system control unit 45R, the process control unit 45RA and the operating and monitoring unit (control and display device) 45RB are marked by an R, since all components are arranged at one side, here the right side of the screed 15. The sensor 41R is connected via cable connection 41k to the process control unit 45RA.

[0050] As shown in Fig. 2, a support mechanism 60R is arranged at the right side of the road finishing machine 10. The distance sensor 41R is preferably arranged at a main support mechanism 61R, which is releasable attached to the right side of the screed 15.

[0051] The distance sensor 41R has the purpose to determine an actual height position of the right side of the screed 15, which can be monitored and controlled. In detail, typically, the actual distance value is compared to a respective set point for the right side, so that the tool

15 can be adjusted with regard to its height at the right side. Expressed in other words, this means that the levelling system 40 is used to control the height of the screed 15.

[0052] The road finishing machine 10 in Fig. 2 comprises furthermore a levelling diagnostic system 300 as described above for Figs. 1a-d.

[0053] Figs. 3, 4 and 5 show the road finishing machine 10 according to Fig. 2, comprising a levelling system 40R with four distance sensors 41R to 44R. It is also conceivable that are only three distance sensors 41R, 43R and 44R arranged, which scan an underground 21 still to be processed and a new pavement layer 22. The sensor system 40R thus comprises at least two distance sensors 41R, 42R and/or 43R in front of the screed 15, which scan the still to be processed underground 21 and determine distance values s1R, s2R and / or s3R to the underground 21 still to be processed, as well as a further distance sensor 44R, which scan the newly laid or new built-in road surface 22 and determines a distance value s4R to the newly laid or newly installed road surface 22.

[0054] A support mechanism 60R for the levelling system 40R is preferably arranged at two points at the right tow arm 13R of the road paver 10. Advantageously, the main support mechanism 61R is releasable secured both in the front region of the tow arm, for example in the immediate vicinity of the tow point, by means of a holder 62R and in the rear region, for example in the immediate vicinity of the attachment of the screed 15, by means of a holder 63R. On the main support mechanism 61, which extends along the direction of travel of the paver 10, further releasable secured and along the main support mechanism 61R slideable holders 64R are arranged, by means of which individual distance sensors 41R to 44R of the sensor system (measurement system / levelling system) 40R are held. For further (fine) adjustment of the outer distance sensors 41R and 44R further releasable secured and displaceable holders 65R are provided. Preferably, the main support mechanism 61R consists of individual or individually connectable mechanical parts or even by means of a twisting mechanism rotatable items or even telescopic items in order to adjust the system in length individually. For known sensor and levelling systems, variable lengths in the range of 9 to 13 meters are common.

[0055] The levelling system 40R comprises a levelling system control unit 45R, consisting essentially of a process control unit 45RA and an operating and monitoring unit (control and display device) 45RB as already described above. The individual distance sensors 41R to 44R are preferably connected via cable connections 41k to 44k to the process control unit 45RA, which reads in and processes the measured distance values s1R to s4R of the distance sensors 41R to 44R. Furthermore, the process control unit 45RA controls the height position of the screed 15 as a function of the measured distance values s1R to s4R, that means the process control unit 45RA functions as a levelling unit. Via the operating and monitoring unit 45RB, an operator, for example the paver screed personnel, can set adjustments or changes to various parameters concerning the levelling or monitor them during the installation process. The operating and monitoring unit 45RB serves as a so-called human-machine interface (HMI or MMI). In a preferred variant, the process control unit 45RA and the operating and monitoring device 45RB are combined in one device or in one housing (as described above), that means components are integrated within one device or housing.

[0056] Fig. 4 show the road finishing machine (paver) 10 illustrated schematically in a bird view, comprising two levelling systems 40L and 40R as described above, whereby each levelling system 40L and 40R comprises four distance sensors 41 L/R ... 44L/R. With these two levelling systems 40L and 40R each machine/tool side (left/right) is controlled (levelled) separately. As already described above, via the operating and monitoring units 45LB and 45RB, the operator, for example the screed personnel, can set adjustments or changes to various parameters concerning the levelling. For instance, the operator can make adjustments manually with regard to the set point of the sensor system (measurement system / levelling system) 40L and/or 40R.

[0057] The road finishing machine 10 comprises furthermore an additional sensor device 200, for instance a cross-slope sensor 200, which is arranged above the main screed 15M, preferably on a crossbeam attached to the screed 15. The cross-slope sensor 200 measures the inclination of the screed 15 transverse to the direction of travel of the road finishing machine 10. The additional sensor device 200 would input into the control loop of one of the levelling systems 40L or 40R, as described in EP 3 795 748 A1.

[0058] Regarding the distance sensors 41L/R ... 44L/R it should be noted that these may be ultrasonic control units, as described in EP 0 542 297 A1 or EP 0 547 378 A1. These sensors typically use three or four ultrasonic sensors because of the fact that the ultrasonic sensors scan the surface at a plurality of widely spaced points, so that elongated bumps in particular are well-balanced.

[0059] The road finishing machine 10 in Figs. 3, 4 and 5 comprises furthermore a levelling diagnostic system 300 as described above for Figs. 1a-d.

[0060] Fig. 5 shows the road finishing machine 10 with an additional wireless communication interface, as described above for Fig. 1d. The levelling system 40L or 40R is connected to the levelling diagnostic system 300, which is for example a software product (App), running on a remote data server system 90 or on a mobile device 80.

[0061] Although the present invention has so far been explained mainly with reference to a road finishing machine, it can also be used on road milling machines.

[0062] Fig. 6 shows a road milling machine 10 illustrated schematically in a side view, comprising a milling drum/milling unit 15 as tool, which is rigidly (fixed) connected / coupled to the chassis 17 (machine body or machine frame) of the road milling machine 10. The road milling machine 10 has two front and two rear landing gears 16F and 16R, whereby in Fig. 6 only the left front and the left rear landing gears 16F and 16R are shown. The road milling machine 10 comprises a levelling system 40L, which consists of three distance sensors 41L, 43L and 44R, which are coupled to the chassis 17 (machine body or machine frame) of the machine 10 and which scan an underground 21 still to be milled and a milled road surface 22. The levelling system 40L thus comprises at least two distance sensors 41L and 43L in front of the milling drum/milling unit 15, which are arranged at a distance a from each other and scan the still to be milled underground 21 and determine distance values to the underground 21 still to be milled, as well as a further distance sensor 44L, which is arranged at a distance a from sensor 43L and scan the milled road surface 22 and determines a distance value to the milled road surface 22. The basic structure of the levelling system 40L shown schematically in Fig. 6 essentially corresponds to the system known from the prior art as described in EP 0 547 378 A1. The sensors 41L, 43L and 44R scan the surface at a plurality of widely spaced points, so that elongated bumps in particular are well-balanced.

[0063] The levelling system 40L further comprises a levelling system control unit 45L, consisting essentially of a process control unit 45A and an operating and monitoring unit (control and display device) 45B. The individual distance sensors 41L, 43L and 44L are preferably connected via cable connections (not shown) to the process control unit 45A, which reads in and processes the measured distance values of the distance sensors 41L, 43L and 44L. Furthermore, the process control unit 45A controls the height position of the milling drum/milling unit 15 as a function of the measured distance values, that means the process control unit 45A functions as a levelling unit. Via the operating and monitoring unit 45B, a machine operator, for example the milling machine personnel, can set adjustments or changes to various parameters concerning the levelling or monitor them during the milling process. The operating and monitoring unit 45B serves as a so-called human-machine interface (HMI or MMI). In a preferred variant, the process control unit 45A and the operating and monitoring unit 45B are combined in one device or in one housing, that means components are integrated within one device or housing, as described above for Figs. 1c and 1d.

[0064] The road milling machine 10 in Fig. 6 comprises furthermore a levelling diagnostic system 300 and an additional wireless communication interface, both have already described above for Figs. 1a-d. The levelling system 40L is connected to the levelling diagnostic system 300, which is for example a software product (App), running on a remote data server system 90 or on a mobile device 80.

[0065] Although some aspects have been described in the context of an apparatus, it is clear that these aspects also represent a description of the corresponding method, where a block or device corresponds to a method step or a feature of a method step. Analogously, aspects described in the context of a method step also represent a description of a corresponding block or item or feature of a corresponding apparatus. Some or all of the method steps may be executed by (or using) a hardware apparatus, like for example, a microprocessor, a programmable computer or an electronic circuit. In some embodiments, some one or more of the most important method steps may be executed by such an apparatus.

[0066] Depending on certain implementation requirements, embodiments of the invention can be implemented in hardware or in software. The implementation can be performed using a digital storage medium, for example a floppy disk, a DVD, a Blu-Ray, a CD, a ROM, a PROM, an EPROM, an EEPROM or a FLASH memory, having electronically readable control signals stored thereon, which cooperate (or are capable of cooperating) with a programmable computer system such that the respective method is performed. Therefore, the digital storage medium may be computer readable.

[0067] Some embodiments according to the invention comprise a data carrier having electronically readable control signals, which are capable of cooperating with a programmable computer system, such that one of the methods described herein is performed.

[0068] Generally, embodiments of the present invention can be implemented as a computer program product with a program code, the program code being operative for performing one of the methods when the computer program product runs on a computer. The program code may for example be stored on a machine readable carrier.

[0069] Other embodiments comprise the computer program for performing one of the methods described herein, stored on a machine readable carrier.

[0070] In other words, an embodiment of the inventive method is, therefore, a computer program having a program code for performing one of the methods described herein, when the computer program runs on a computer, a mobile process control computer or the like.

[0071] A further embodiment of the inventive methods is, therefore, a data carrier (or a digital storage medium, or a computer-readable medium) comprising, recorded thereon, the computer program for performing one of the methods described herein. The data carrier, the digital storage medium or the recorded medium are typically tangible and/or nontransitionary.

[0072] A further embodiment of the inventive method is, therefore, a data stream or a sequence of signals representing the computer program for performing one of the methods described herein. The data stream or the sequence of signals may for example be configured to be transferred via a data communication connection, for example via the Internet.

[0073] A further embodiment comprises a processing means, for example a computer, or a programmable logic device, configured to or adapted to perform one of the methods described herein.

[0074] A further embodiment comprises a computer having installed thereon the computer program for performing one of the methods described herein.

[0075] A further embodiment according to the invention comprises an apparatus or a system configured to transfer (for example, electronically or optically) a computer program for performing one of the methods described herein to a receiver. The receiver may, for example, be a computer, a mobile device, a memory device or the like. The apparatus or system may, for example, comprise a file server for transferring the computer program to the receiver.

[0076] In some embodiments, a programmable logic device (for example a field programmable gate array) may be used to perform some or all of the functionalities of the methods described herein. In some embodiments, a field programmable gate array may cooperate with a microprocessor in order to perform one of the methods described herein. Generally, the methods are preferably performed by any hardware apparatus.

[0077] The above described embodiments are merely illustrative for the principles of the present invention. It is understood that modifications and variations of the arrangements and the details described herein will be apparent to others skilled in the art. It is the intent, therefore, to be limited only by the scope of the impending patent claims and not by the specific details presented by way of description and explanation of the embodiments herein.

List of reference numerals:

[0078]

10	Asphalt paver (road finishing machine) / Road milling machine
11	Control platform
12	Hopper (material bunker)
13L/R	Tow arm (left/right)
14	Auger
15	Screed/Milling drum (milling unit)
15M	Main screed
15L/R	Screed extensions (left/right)
16F/R	Front and rear landing gear
17	Chassis (machine body or machine frame)
21	Underground to be asphalted
22	Newly applied road surface
40L/R	levelling system (measurement system / sensor system) (left/right)
41...44	Sensors (e. g. Distance Sensors,...)
41L/R... 44L/R	Distance sensors (left/right)
41k...44k	Cable connection
45,45L/R	Levelling system control unit (left/right)
45A,45LA/RA	Process control unit (left/right)
45B,45LB/RB	Operating and monitoring unit (left/right)
51,52	Actuators (e. g. Valves, Valves Controller, ...)
60L/R	Levelling system support mechanism (left/right)
61L/R	Main support mechanism (left/right)
62L/R, 63L/R	Mechanical holders (left/right)
64L/R, 65L/R	Slidable mechanical holders for distance sensors (left/right)
70	Wireless communication interface unit
70k	Cable connection
80	Mobile device (laptop computer, smartphone or any other kind of mobile or portable device)
85	Communication unit
90	Data server system
71,72,81, 91	Communication links
95	Network
110-130	Method steps
200	Additional Sensor (e. g. Cross-Slope Sensor, 3D Process control system)
300	Levelling diagnostic system
301,302,303	Connections
s1R...s4R	Distance/Height
m1...m3	Sensor values
P1,P2	Patterns

Claims

1. Method (100) for evaluating of a quality of a generated pavement or a generated surface, generated by use of a construction machine (10), especially a road construction machine, road finishing machine or milling machine (10), comprising the following steps:

    receiving sensor values from one or more sensors (41...44) and/or a sensor system of the construction machine (10);
    determining a specific sensor value combination within the sensor values, the specific sensor value combination being assigned to a specific quality situation; and
    outputting an operator message dependent on the specific quality situation.

2. Method (100) according to claim 1, wherein the specific value combination is out of a plurality of specific value combinations; and/or
wherein a specific sensor value combination is out of a plurality of specific sensor value combinations stored by a database.

3. Method (100) according to claim 2, wherein the plurality of specific sensor value combinations comprises another specific sensor value combination being

assigned to another specific quality situation, such that another operator message can be output dependent on the another specific quality situation.

4. Method (100) according to one of the previous claims, wherein the operator message comprises an information regarding the specific quality situation and/or a suggestion for improving the specific quality situation and/or an information on a parameter to be adapted or an actuator value to be adapted.

5. Method according to one of the previous claims, wherein the sensor values are received over time and wherein the sensor value combination is determined taking into account a value deviation of sensor values received over the time of at least one sensor value of the sensor values.

6. Method (100) according to one of the previous claims, further comprising the step of receiving one or more actuator values or one or more process control parameters, wherein the step of determining is performed taking into account the one or more actuator values and/or the one or more process control parameters.

7. Method (100) according to one of the previous claims, wherein one sensor value of the sensor values and/or an actuator value is received from a levelling system of the construction machine (10).

8. Method (100) according to one of the previous claims, wherein one sensor value of the sensor values is determined using a distance sensor, a cross slope sensor and/or a 3D process control system.

9. Method (100) according to one of claims 6 to 8 having a back reference to claim 6, wherein an actuator value of the one or more actuator values describes a height position of a tool or a screed, and/or a width information of the tool or the screed, and/or a speed information of the construction machine (10); and/or wherein a process control parameter comprises a temperature information and/or a material temperature information of a paving and/or an RPM information of a milling drum.

10. Method (100) according to one of the previous claims, wherein a sensor value of the sensor values or an actuator value and/or a process control parameter are extracted from a CAN bus.

11. Computer program for performing, when running on a computer the method (100) according to one of the previous claims.

12. Diagnosis control unit for evaluating of a quality of a generated pavement or generated surface, generated by use of a construction machine (10), especially a work construction machine (10), a paving machine or a milling machine (10), the process control unit (45A,45LA/RA) comprising:

    an interface for receiving sensor values from one or more sensors (41...44) and/or a sensor system of the construction machine (10);
    a processor configured to determine a specific sensor value combination within the sensor values, the specific sensor value combination being associated with a specific quality situation; and
    an interface for outputting an operator message dependent on the specific quality situation.

13. Diagnosis control unit according to claim 12, wherein the interface for receiving sensor values comprises a CAN bus interface; and/or
wherein the interface for outputting an operation message comprises a human machine interface and/or a wireless communication link to a mobile device (80).

14. Diagnosis system according to claim 12 or 13, wherein the diagnosis control unit further comprises a database or an interface for generating access to a database, the database storing a plurality of specific sensor value combinations.

15. Leveling system, process control unit (45A,45LA/RA) or smart device comprising the diagnosis control unit according to claim 12, 13, or 14.

16. Construction machine (10), especially a road construction machine (10), a paving machine (10) or a milling machine (10) comprising a diagnosis control unit according to claim 12, 13, or 14, or a leveling system, a process control unit (45A,45LA/RA) or smart device according to claim 15.

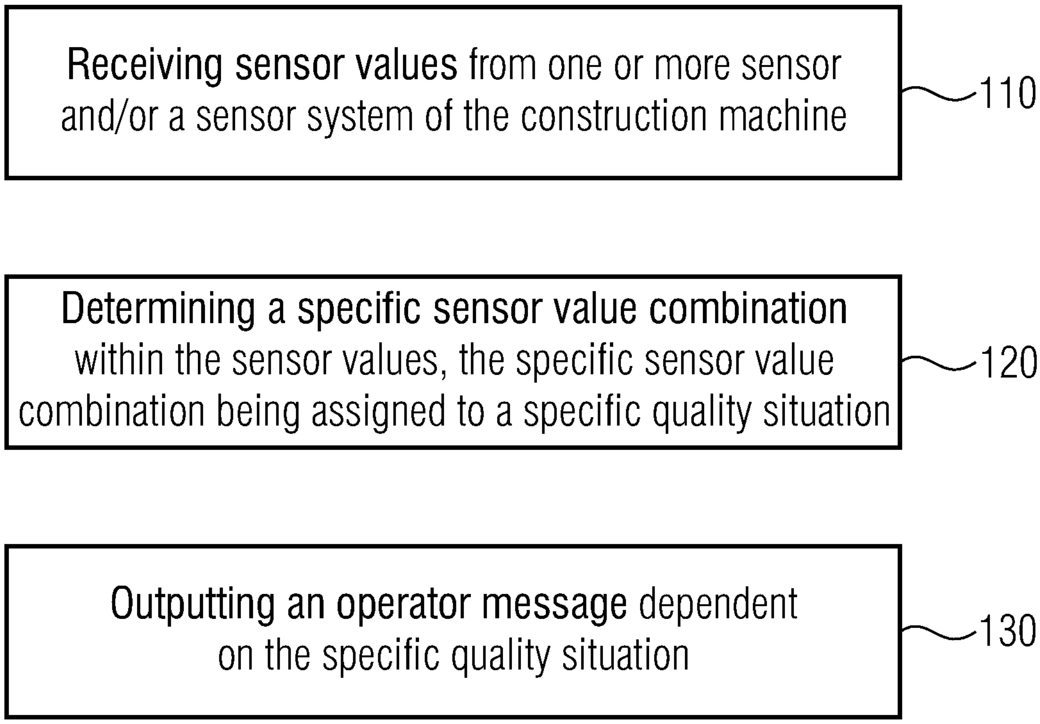

Receiving sensor values from one or more sensor and/or a sensor system of the construction machine
110
Determining a specific sensor value combination within the sensor values, the specific sensor value combination being assigned to a specific quality situation
120
Outputting an operator message dependent on the specific quality situation
130

Fig. 1a

	P1	P2
m1	2	3
m2	4	3
m3	3	3

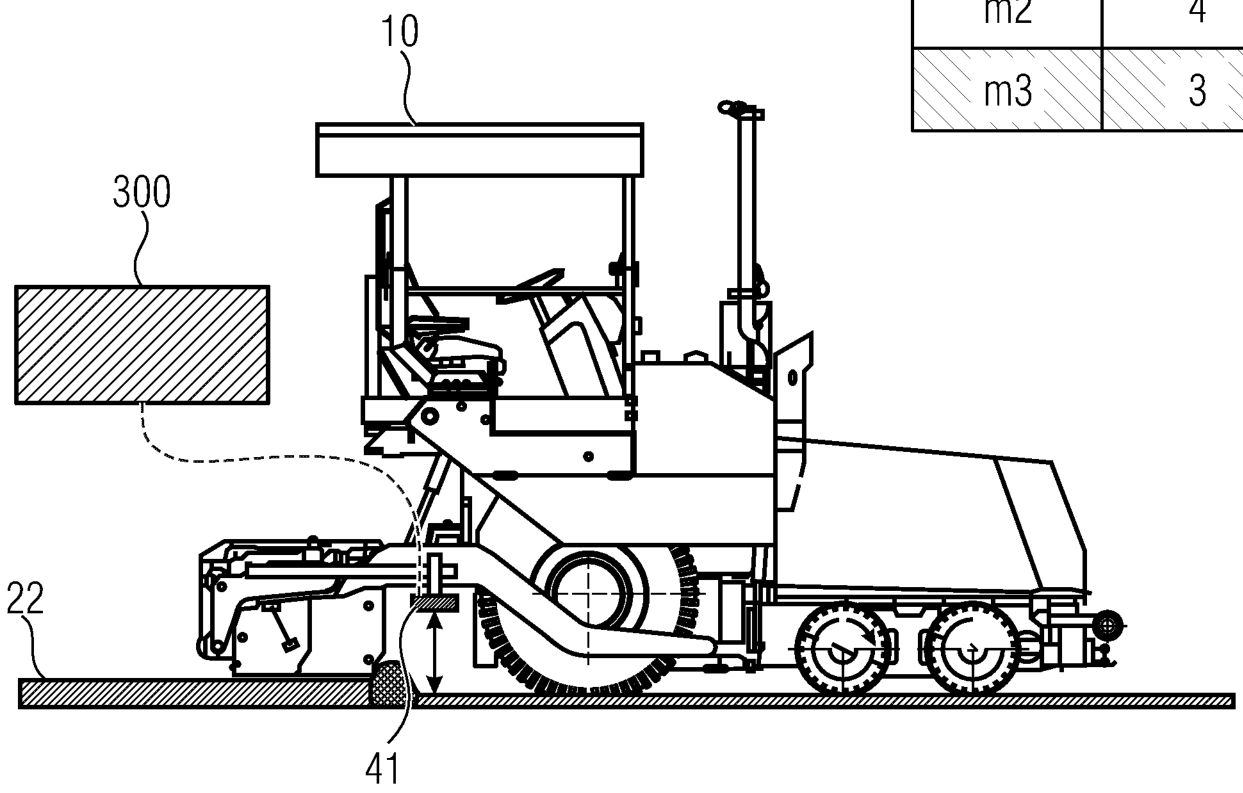


Fig. 1b

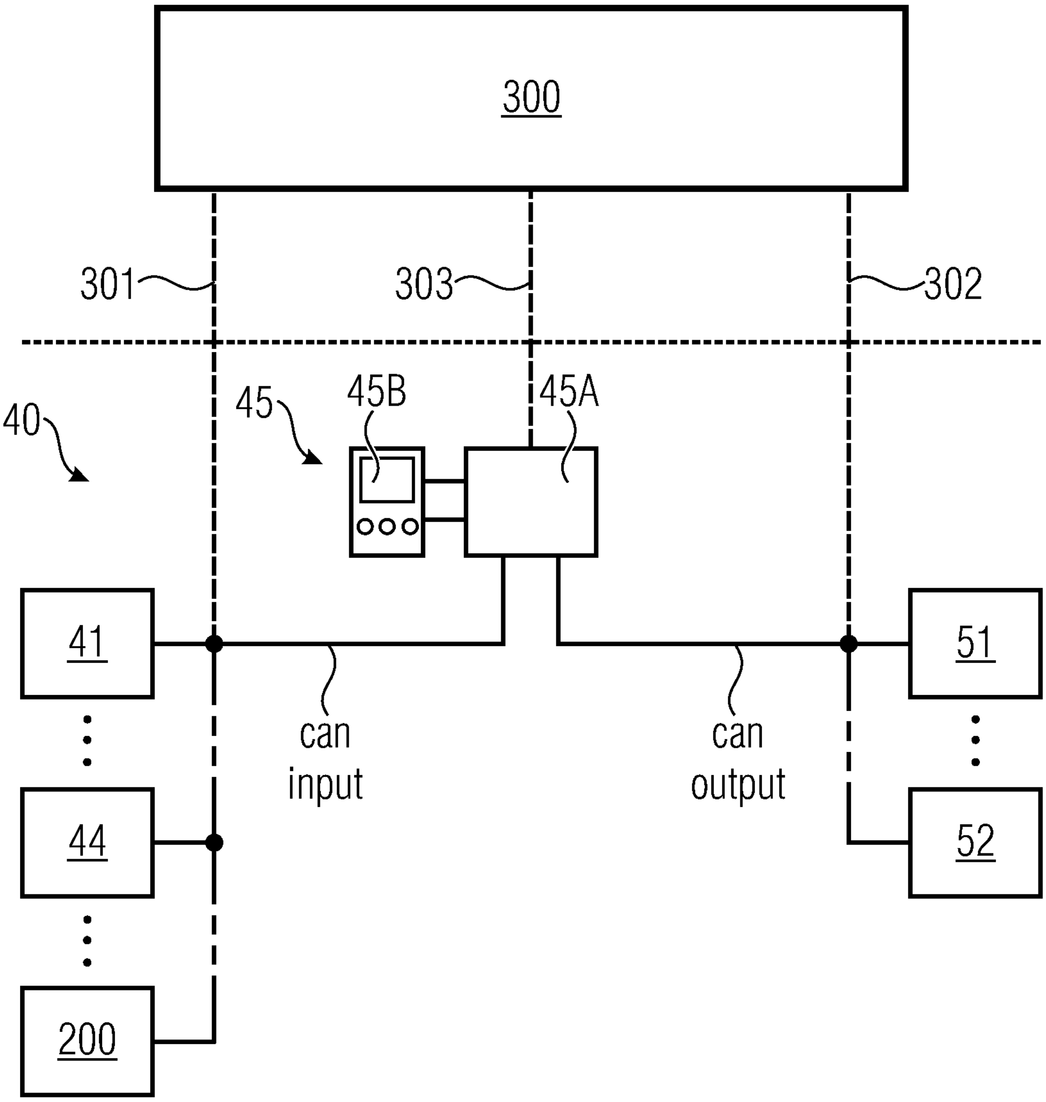

300
301
303
302
40
45
45B
45A
41
44
200
51
52
can
input
can
output

Fig. 1c

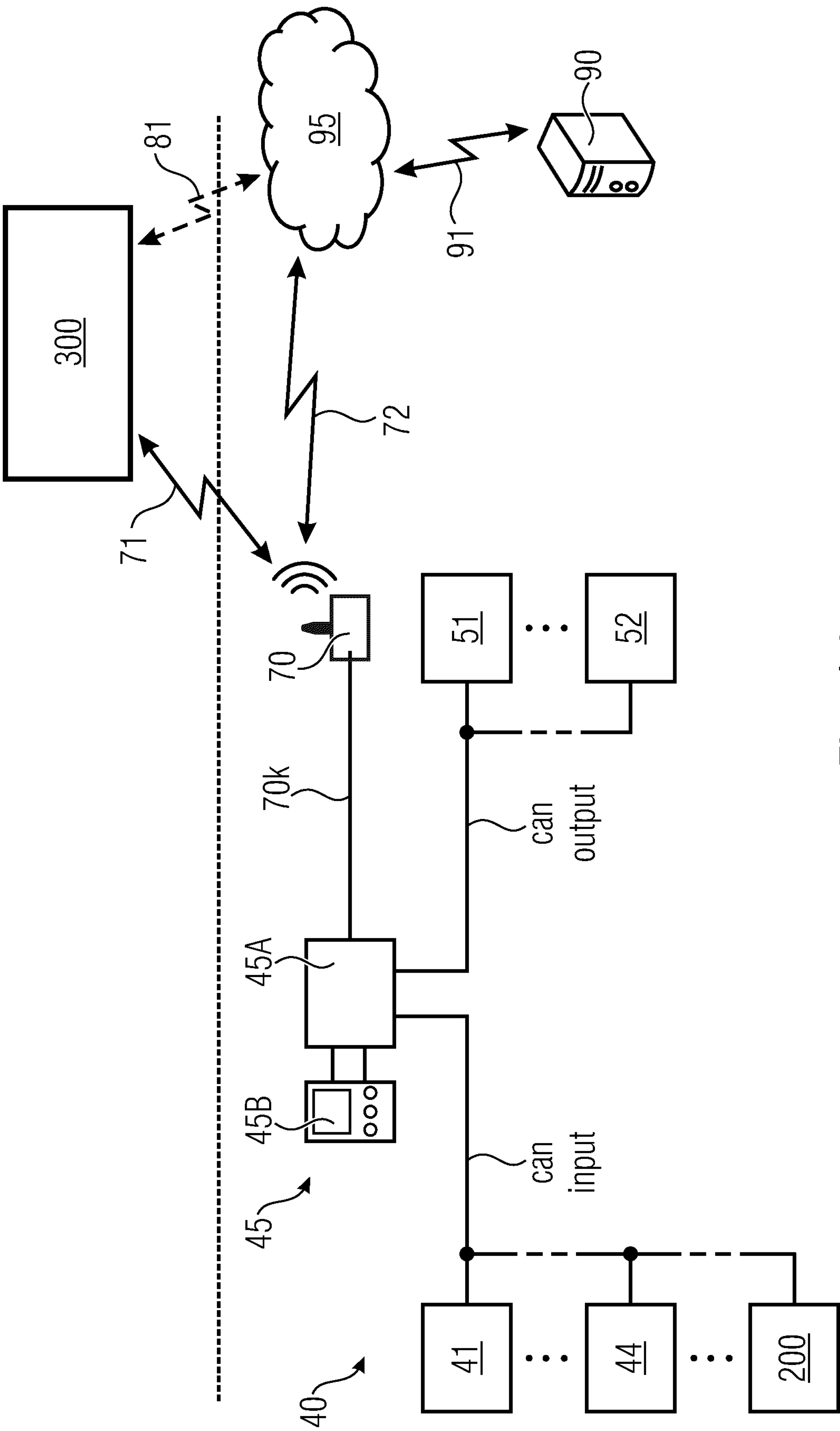

300
81
95
90
91
72
71
70
70k
51
52
can output
45A
45B
45
can input
40
41
44
200

Fig. 1d

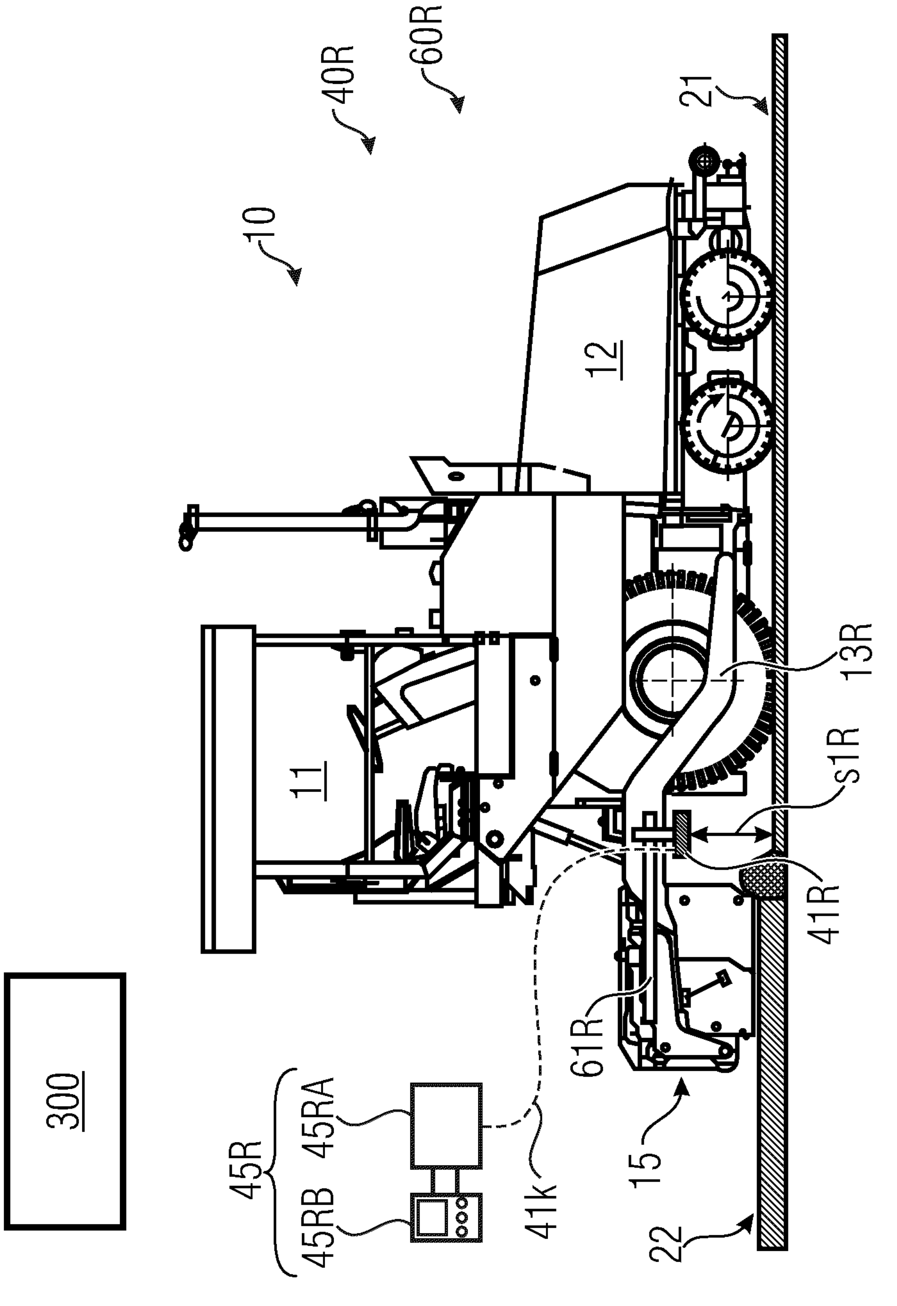


Fig. 2

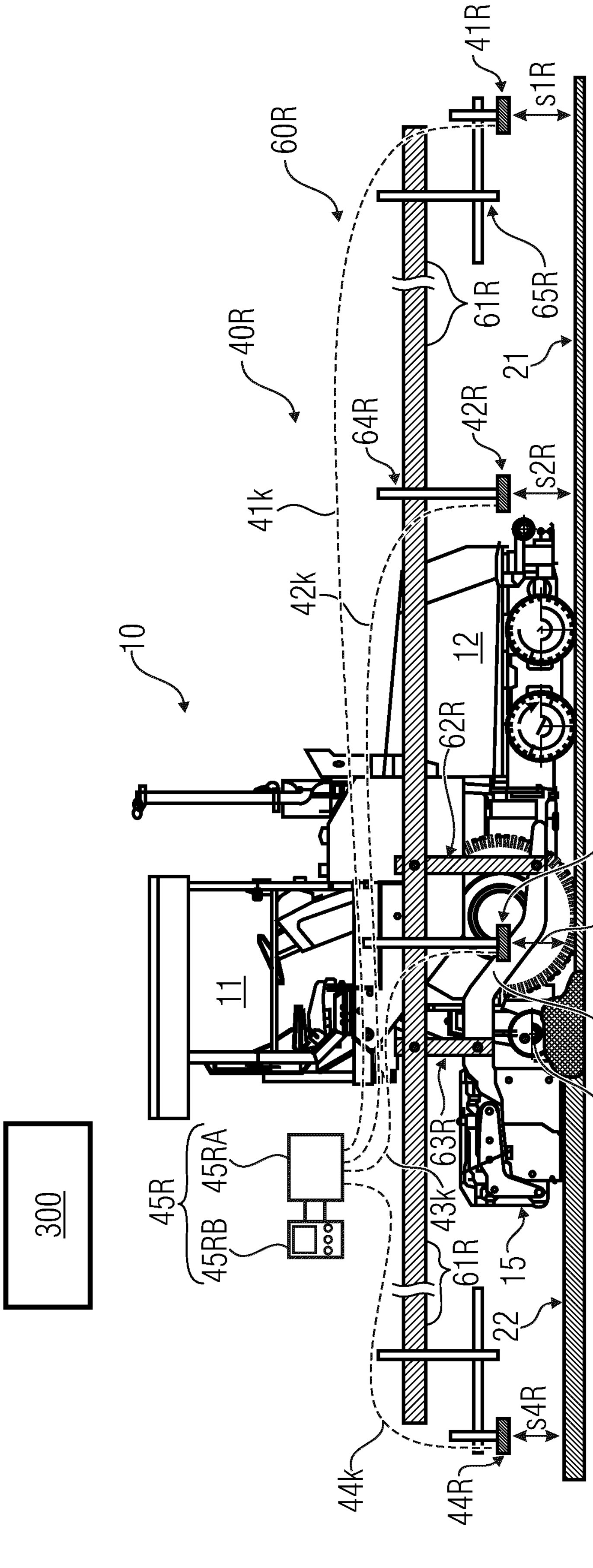
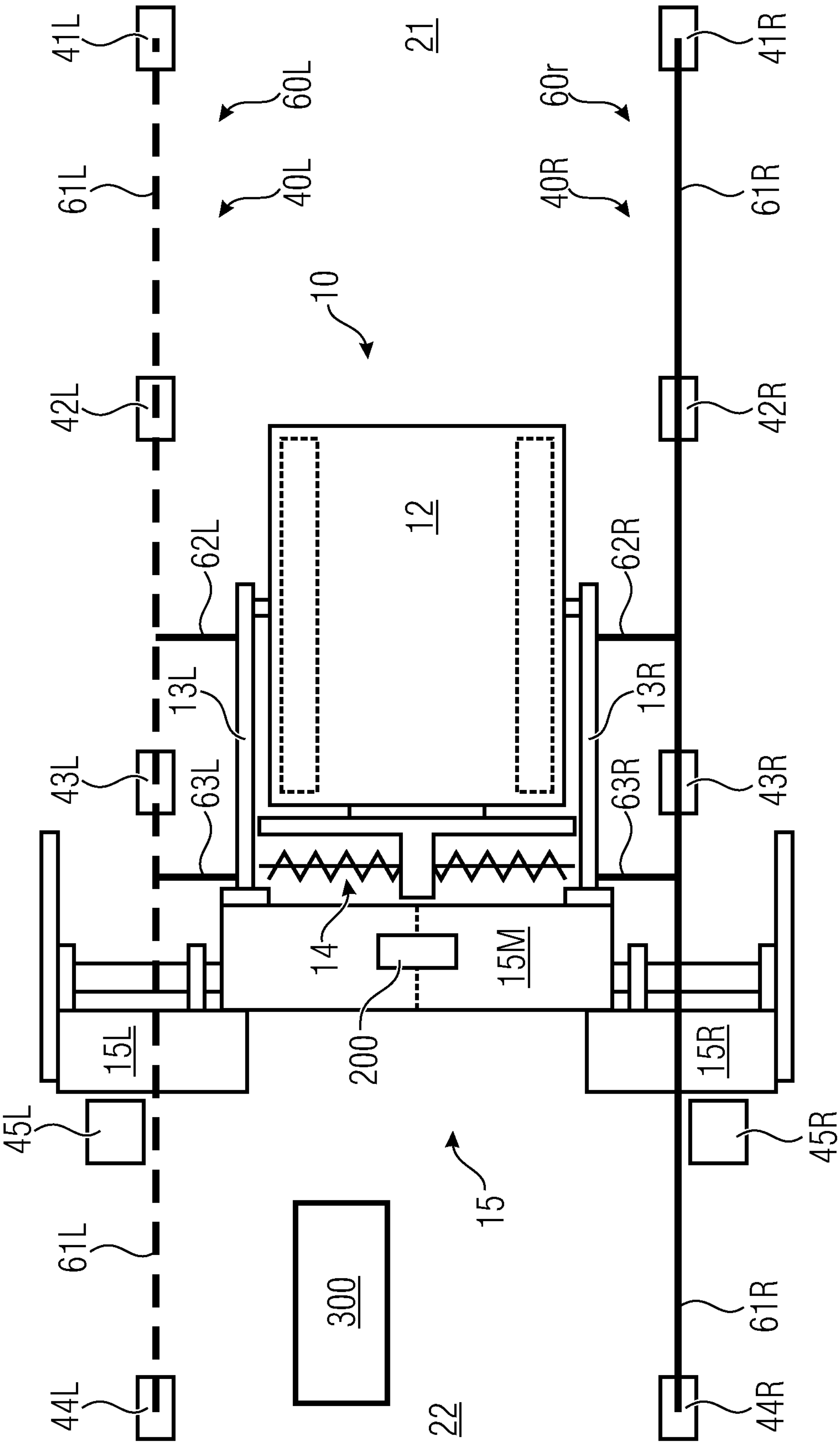

41R
s1R
60R
65R
61R
40R
21
42R
64R
s2R
41k
42k
12
10
62R
43R
s3R
11
13R
14
45RA
63R
43k
45R
300
45RB
15
61R
22
s4R
44k
44R

Fig. 3


41L
21
41R
60L
60r
61L
40L
40R
61R
10
42L
42R
12
62L
62R
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13R
43L
63L
63R
43R
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61L
300
61R
44L
22
44R

Fig. 4

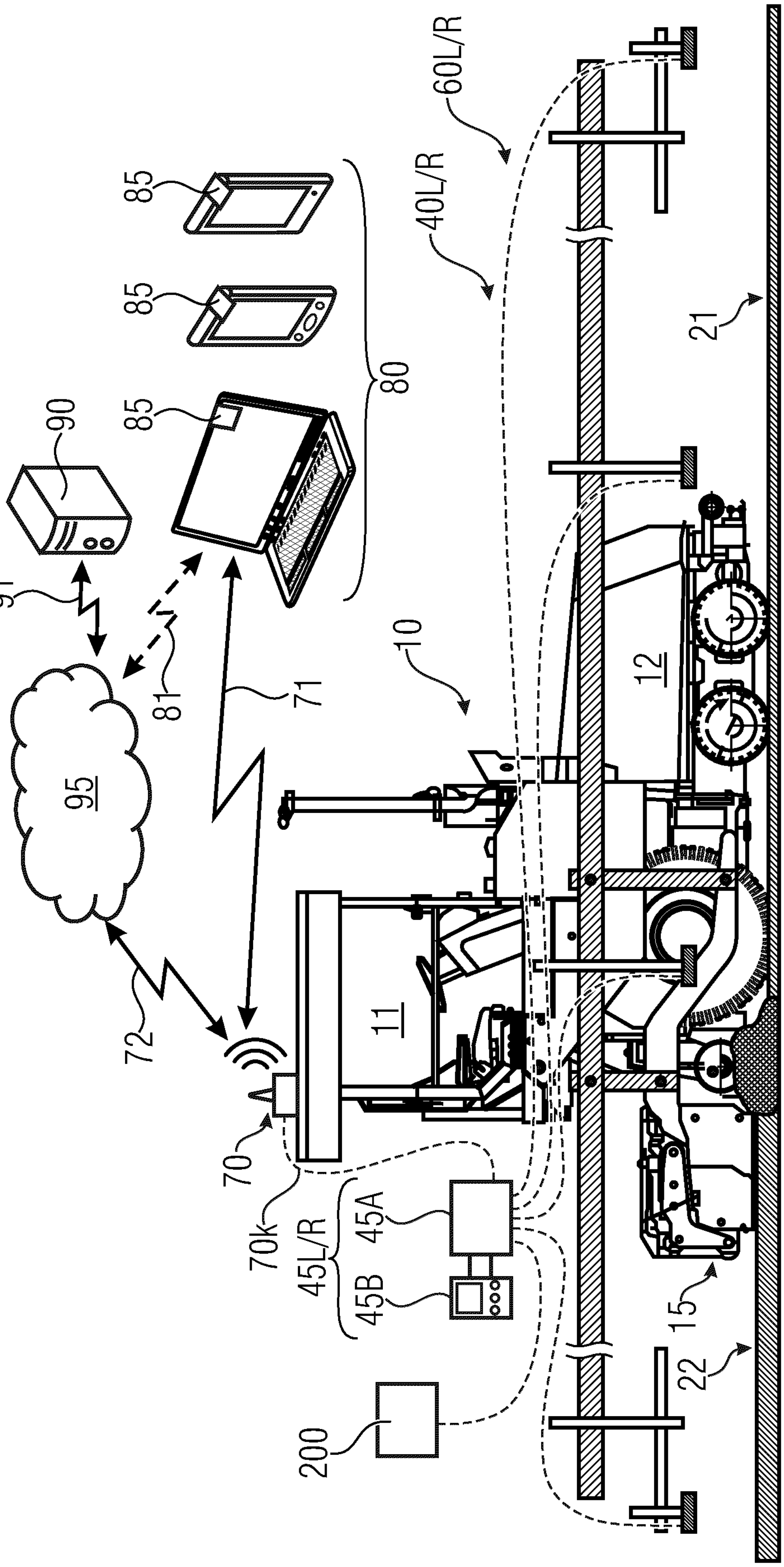
60L/R
40L/R
85
85
85
90
80
91
81
95
71
10
12
21
72
11
70
70k
45L/R
45A
45B
15
22
200

Fig. 5

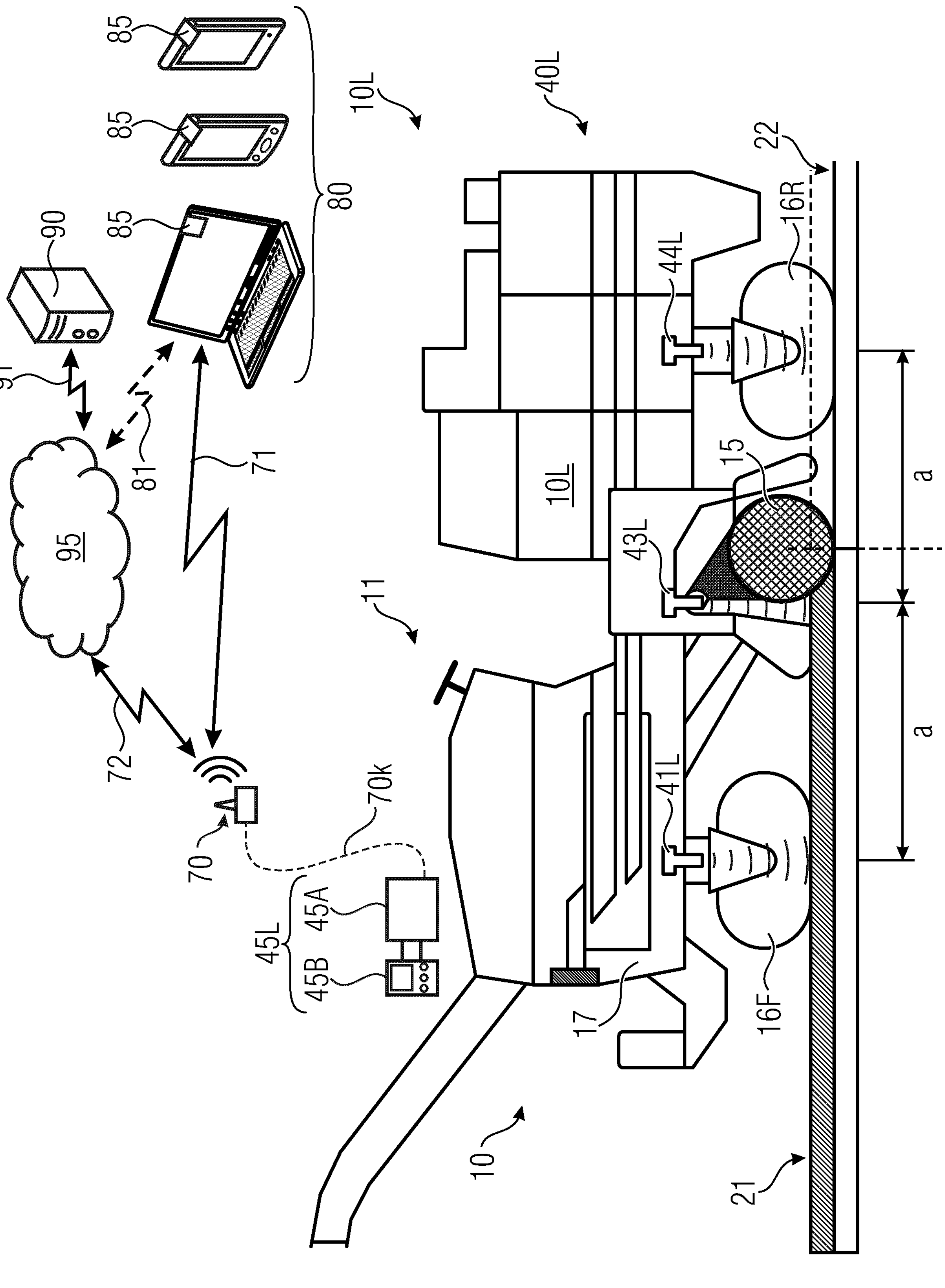
85
85
85
90
91
80
10L
40L
95
81
71
22
16R
44L
10L
15
43L
11
72
70k
41L
70
45A
45L
45B
a
a
17
16F
10
21

Fig. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 21 20 0051

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E01C

2

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	22 February 2022	Kerouach, May

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