



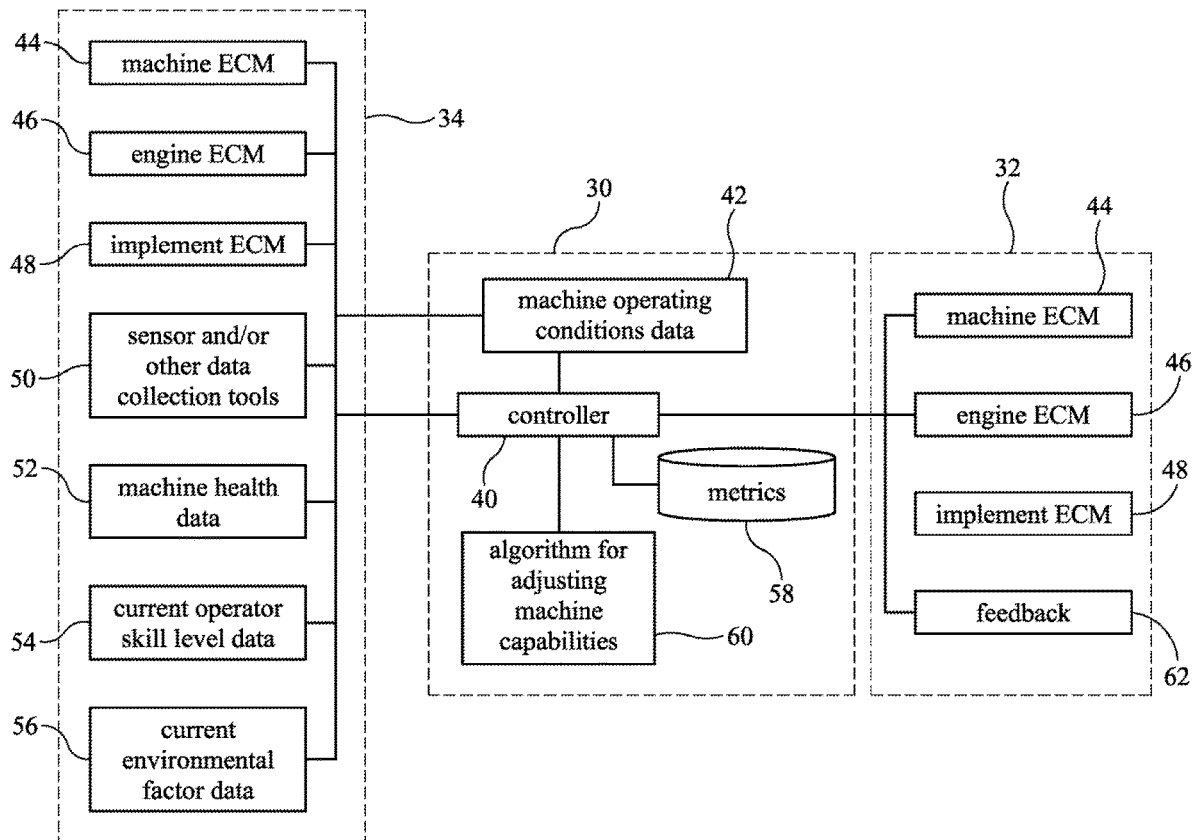
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(19) **United States**(12) **Patent Application Publication**
Weber et al.(10) **Pub. No.: US 2020/0048866 A1**(43) **Pub. Date: Feb. 13, 2020**(54) **SYSTEM AND COMPUTERIZED METHOD
FOR ADJUSTING MACHINE CAPABILITIES
IN RESPONSE TO MACHINE OPERATING
CONDITIONS**(52) **U.S. Cl.**CPC *E02F 9/2025* (2013.01); *E02F 3/7609*
(2013.01); *E02F 9/24* (2013.01); *E02F 9/26*
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ABSTRACT(72) Inventors: **Michael Adam Weber**, Peoria, IL (US);
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A computerized method for adjusting machine capabilities of a machine in response to machine operating conditions is provided. The computerized method is carried out by a controller and includes: collecting data corresponding to the machine operating conditions using the controller. The data includes current machine health data, current operator skill level data, and current environmental factor data. The computerized method also includes comparing the machine operating conditions against stored metrics using the controller. When the machine operating conditions are below the stored metrics, the controller decreases the machine capabilities. When the machine operating conditions are above the stored metrics, the controller increases the machine capabilities.

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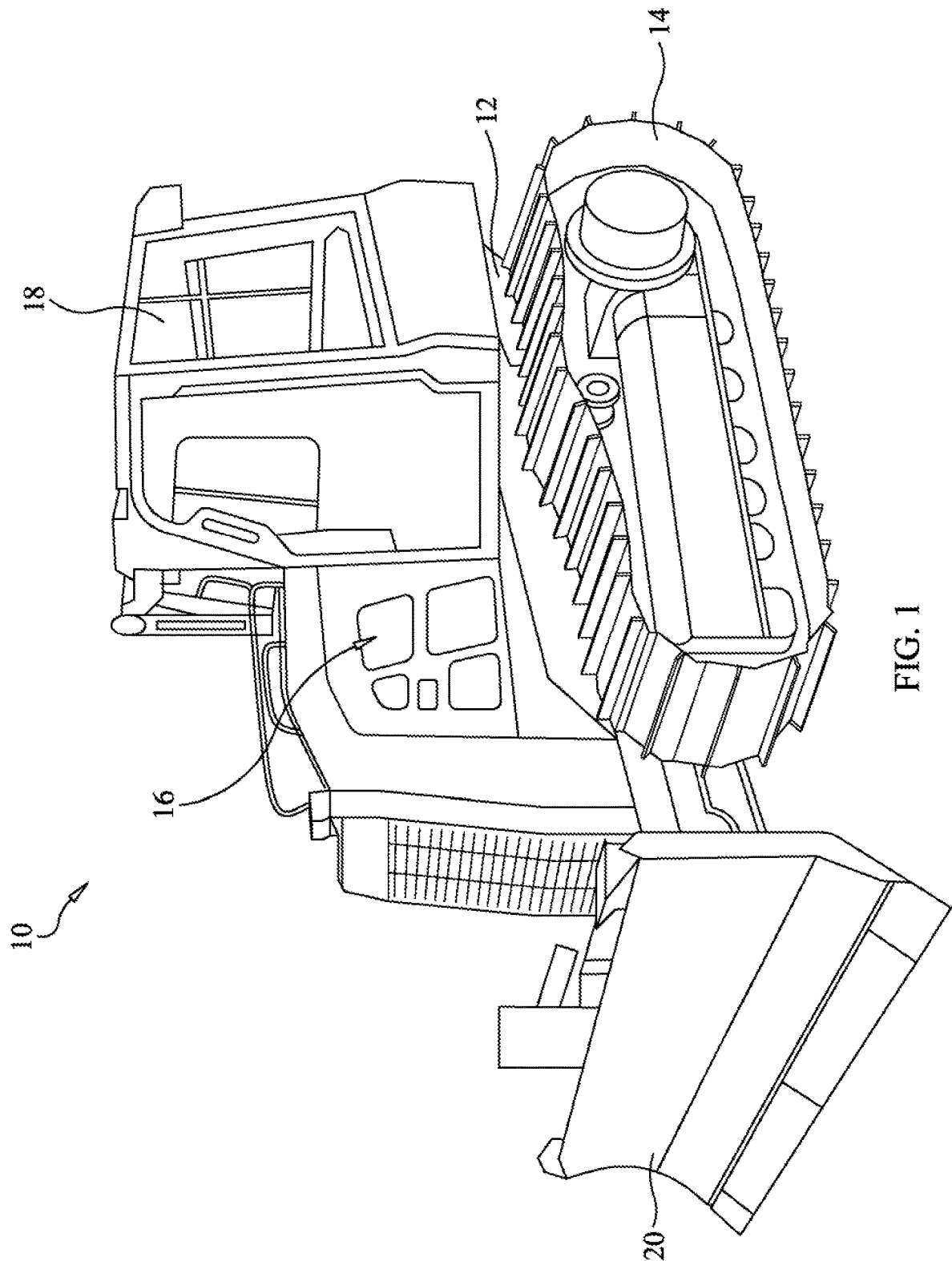


FIG. 1

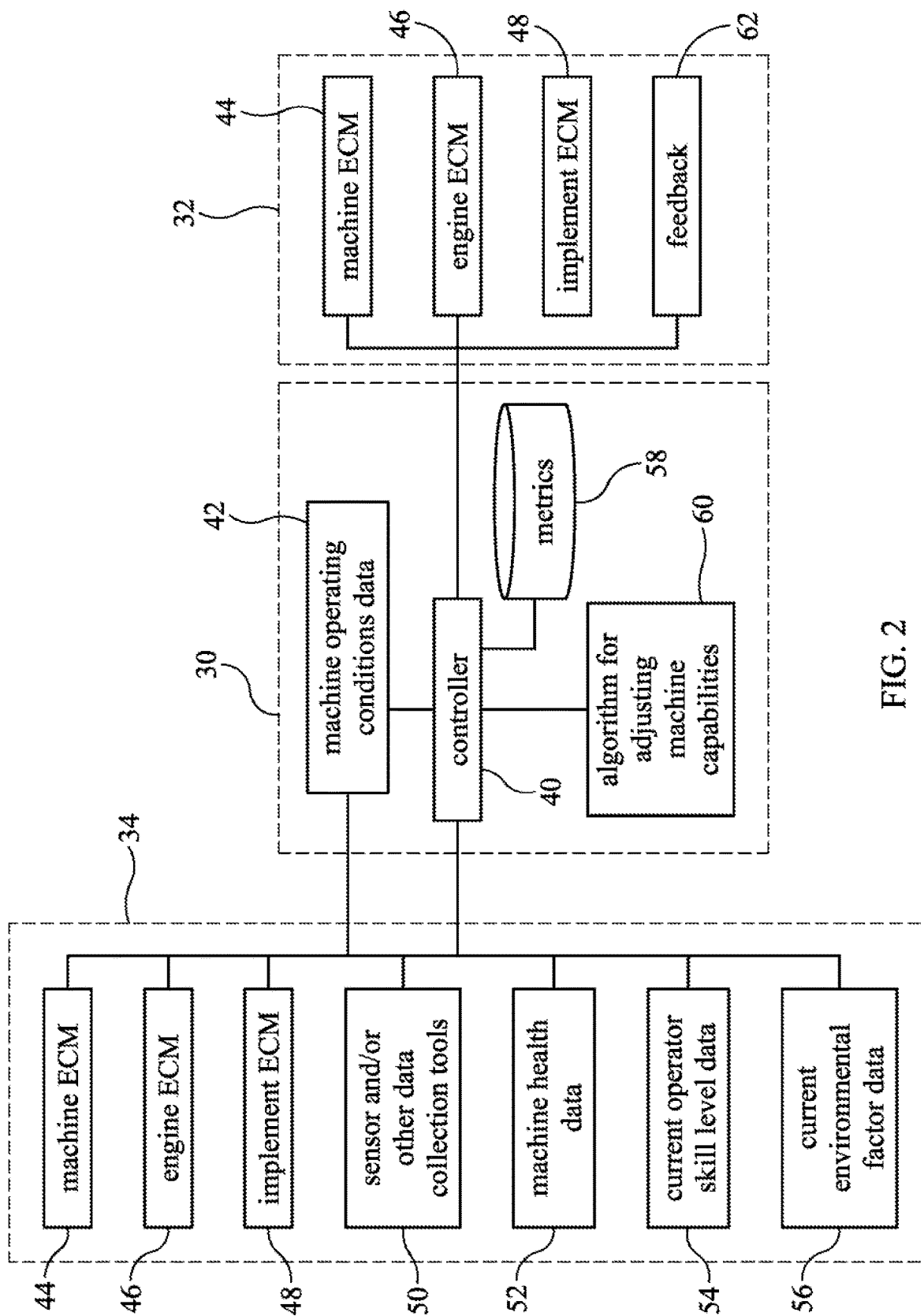


FIG. 2

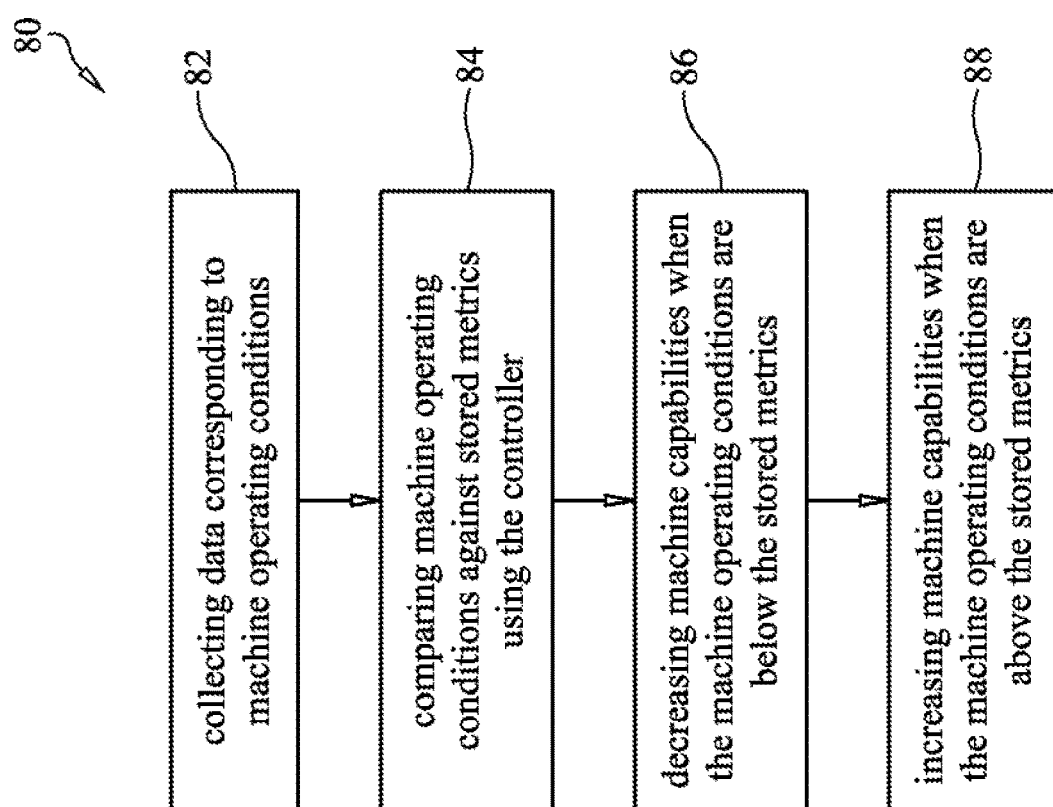


FIG. 3

SYSTEM AND COMPUTERIZED METHOD FOR ADJUSTING MACHINE CAPABILITIES IN RESPONSE TO MACHINE OPERATING CONDITIONS

TECHNICAL FIELD

[0001] The present disclosure relates generally to adjusting machine capabilities and, more particularly, to a system and method for automatically adjusting machine capabilities based on current machine operating conditions.

BACKGROUND

[0002] Construction and mining equipment, such as, for example, wheel loaders, dozers, mining trucks, and other machines, include implements, or attachments, to perform a variety of tasks, including repeated tasks of a work cycle, at a worksite. Operators who operate these machines may need to acquire certain skills or training over time to efficiently operate the machines to perform desired tasks at the worksite. For the operators to understand his or her strengths and weaknesses in operating the machine, the operators may need to be given periodic feedback so that the operators may be coached correctly and adequately based on his or her customized needs. This feedback is typically manual.

[0003] Training new operators can take time and a lot of effort, and while the operator is increasing their skills, less work is being done, the machine may sometimes be abused, and the operator is much more likely to be fatigued because of the mental workload before machine operations get more comfortable and less taxing for that operator.

[0004] U.S. Patent Application Publication No. 2017/0098182 to La Reau et al. discusses a performance monitoring system associated with a machine. The system includes a sensor assembly configured to generate data of one or more parameters associated with an operation of the machine. The system further includes a controller communicably coupled to the sensor assembly. The controller is configured to determine a list of performance parameters associated with a performance of an operator while operating the machine. The controller selects a set of performance parameters from the list of performance parameters. The controller receives the data associated with the set of performance parameters from the sensor assembly. The controller compares the data associated with the set of performance parameters with respective predetermined thresholds. The controller evaluates the performance of the operator based on the comparison. Also, the controller displays a visual cue to the operator. The visual cue is indicative of the performance of the operator based on the evaluation.

SUMMARY OF THE INVENTION

[0005] In one aspect, a computerized method for adjusting machine capabilities of a machine in response to machine operating conditions is provided. The computerized method is carried out by a controller and includes collecting data corresponding to the machine operating conditions using the controller. The data includes current machine health data, current operator skill level data, and current environmental factor data. The computerized method also includes comparing the machine operating conditions against stored metrics using the controller. When the machine operating conditions are below the stored metrics, the controller decreases

the machine capabilities. When the machine operating conditions are above the stored metrics, the controller increases the machine capabilities.

[0006] In another aspect, a machine includes a machine frame, ground-engaging elements supported on the machine frame, and an engine supported on the machine frame and drivably connected to the ground engaging elements. The machine also includes a controller supported on the machine and carrying out the following: collecting data corresponding to machine operating conditions using the controller, wherein the data includes current machine health data, current operator skill level data, and current environmental factor data; comparing the machine operating conditions against stored metrics using the controller; decreasing machine capabilities, using the controller, when the machine operating conditions are below the stored metrics; and increasing machine capabilities, using the controller, when the machine operating conditions are above the stored metrics.

[0007] In yet another aspect, a computer readable medium including non-transitory computer readable code is provided. The computer readable code provides instructions for collecting data corresponding to machine operating conditions. The data includes current machine health data, current operator skill level data, and current environmental factor data. Instructions are also provided for comparing the machine operating conditions against stored metrics. Machine capabilities are decreased when the machine operating conditions are below the stored metrics, and machine capabilities are increased when the machine operating conditions are above the stored metrics.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 is a perspective view of an exemplary machine, according to an aspect of the present disclosure;

[0009] FIG. 2 is a simplified block diagram of an exemplary system for adjusting machine capabilities of the exemplary machine of FIG. 1, according to another aspect of the present disclosure; and

[0010] FIG. 3 is a flow diagram of an exemplary computerized method for adjusting machine capabilities of the exemplary machine of FIG. 1, using the system of FIG. 2, according to another aspect of the present disclosure.

DETAILED DESCRIPTION

[0011] An exemplary machine 10, according to the present disclosure, is shown in FIG. 1. The machine 10 may be a tracked dozer, as shown, or may be any other off-highway or on-highway machine compatible with the systems and strategies disclosed herein. Generally, the machine 10 may include a machine frame 12, ground-engaging elements 14, such as tracks or wheels, supported on the machine frame 12, and an engine 16 supported on the machine frame 12 and drivably connected to the ground-engaging elements 14 via a drive system. Drive systems, and/or power systems, may include the engine 16, a motor, a transmission, and/or additional or alternative components for propelling, powering and/or driving the machine 10, or various components or system thereof.

[0012] The machine 10 may also include an operator control station 18 supported on the machine frame 12 and housing a number of machine controls, which may be used by an operator to operate the machine 10 and/or control

various operational aspects of the machine 10. The machine controls, and other components or devices, may be used by the operator to electronically, hydraulically, mechanically and/or otherwise control movement of the machine 10, such as by controlling the drive system and, ultimately, the ground-engaging elements 14.

[0013] The machine controls may also be used to electronically, hydraulically, mechanically and/or otherwise, control operation and movement of an implement 20, such as a blade, as shown, or any other machine implement or attachment. In addition to, or as an alternative to, typical operator-controlled operation, as just described, control of the machine 10 may be autonomous, semi-autonomous, or remote, for example. Although a specific machine is illustrated, it should be appreciated that the concepts described herein are applicable to a wide variety of machines capable of a wide variety of operations.

[0014] As will be discussed in greater detail below, the machine 10 may be manufactured having a predetermined or predefined set of machine performance capabilities. For example, the machine 10 may have a specific maximum engine performance, steering performance, machine speed, control response speed, implement response speed, etc. As should be clear, and become more apparent below, machine performance capabilities may represent ranges or maximums of machine operation, including a variety of areas of machine operation and/or performance.

[0015] Referring also to FIG. 2, a controller, or electronic controller, 40 may be supported on the machine frame 12 and may be part of a control system 30 for the machine 10. As described herein, the controller 40, or control system 30 in general, may be configured to adjust machine capabilities 32 of the machine 10 in response to machine operating conditions 34. The controller 40 may include a processor, such as, for example, a central processing unit, a memory, and an input/output circuit that facilitates communications internal and external to the controller 40. The processor may control operation of the controller 40 by executing operating instructions, such as, for example, computer readable program code stored in the memory, wherein operations may be initiated internally or externally to the controller 40.

[0016] A control scheme, an example of which is provided below, may be utilized that monitors outputs of systems or devices, such as, for example, sensors, actuators, or control units, via the input/output circuit and controls inputs to various other systems or devices. For example, and as will be described below, the controller 40 may receive various data, and may perform operations responsive to receipt of the data. The operations performed responsive to receipt of the data may correspond to an algorithm for adjusting machine capabilities 32 based on machine operating conditions 34, 42 stored in memory and may utilize additional information stored in memory. The memory may comprise temporary storage areas, such as, for example, cache, virtual memory, or random access memory, or permanent storage areas, such as, for example, read-only memory, removable drives, network/internet storage, hard drives, flash memory, memory sticks, or any other known volatile or non-volatile data storage devices.

[0017] The controller 40 may collect data corresponding to the machine operating conditions 34, 42, such as data from a machine electronic control module 44, an engine electronic control module 46, an implement electronic control module 48, and sensors and/or other data collection tools

50. Additionally, or alternatively, the controller 40 may collect, receive, or derive machine health data 52, current operator skill level data 54, and/or current environmental factor data 56.

[0018] Machine operating conditions 34, 42 may represent a wide variety of data exemplifying how the machine 10 is currently performing, as defined by a particular implementation of the strategies disclosed herein. As described herein, the data may be selected to represent how the operator is operating the machine 10 (e.g., the skill level of the operator), the current environment (e.g., weather and the like) and how it is impacting operation of the machine 10, and the current operation of the machine 10 based on how various machine components are operating (e.g., whether components are performing as they should, or overheating, or the like).

[0019] The current machine health data 52 may be derived from one or more of a temperature sensor, pressure sensor, and strain gauge, for example. The current operator skill level data 54 may be derived from one or more of payload production, fuel efficiency, bucket load time, bucket fill time, and near misses, for example. And, for example, the current environmental factor data 56 may be derived from one or more of wind, water, humidity, temperature, movement, and pressure.

[0020] As will be described in more detail below, the machine operating conditions data 42 may be compared against stored metrics 58 using the controller 40 and an algorithm for adjusting machine capabilities 60 to adjust machine capabilities 32. For example, the controller 40 may decrease the machine capabilities 32 when the machine operating conditions 34, 42 are below the stored metrics. Additionally or alternatively, the controller 40 may increase the machine capabilities 32 when the machine operating conditions 34, 42 are above the stored metrics.

[0021] According to an example, decreasing the machine capabilities 32 may include decreasing at least one of machine component speed and machine component power, whereas increasing the machine capabilities 32 may include increasing at least one of machine component speed and machine component power. Of course, increasing or decreasing, or otherwise modifying, various other machine capabilities 32, in addition to or as an alternative to speed and/or power, may also be incorporated into the present disclosure. Yet alternatively, machine capabilities 32 may be adjusted under alternative conditions.

[0022] Either or both of the increasing and decreasing of the machine capabilities 32 may include increasing or decreasing the machine capabilities 32 by an incremental percentage corresponding to the machine operating conditions 34, 42. Further, increasing and/or decreasing the machine capabilities 32 may, for example, include altering control signals to one or more of the machine electronic control module 44, the engine electronic control module 46, and the implement electronic control module 48, as will be described below. For example, signals may be sent to adjust specific maximum engine performance, steering performance, machine speed, control response speed, and/or implement response speed, or the like.

INDUSTRIAL APPLICABILITY

[0023] The present disclosure relates generally to a system and method for monitoring machine operating conditions. Further, the present disclosure is applicable to adjusting

machine capabilities based on the machine operating conditions. The system and method may be particularly applicable to matching machine capabilities to current operating conditions, including, for example, operator skill level, machine health data, and/or environmental factors.

[0024] Referring to FIGS. 1-3, an exemplary machine may include a machine frame 12, ground-engaging elements 14, such as tracks or wheels, supported on the machine frame 12, and an engine 16 supported on the machine frame 12 and drivingly connected to the ground-engaging elements 14 via a drive system. The machine 10 may also include an operator control station 18 supported on the machine frame 12 and housing a number of machine controls, which may be used by an operator to operate the machine 10 and/or control various operational aspects of the machine 10.

[0025] The machine 10 may be manufactured having a predetermined or predefined set of machine capabilities 32. For example, the machine 10 may have a specific maximum engine performance, steering performance, machine speed, control response speed, implement response speed, etc. However, these machine capabilities 32 may not be appropriate for new operators. Training new operators can take time and a lot of effort, and while the operator is increasing their skills, less work is being done, the machine 10 may sometimes be abused, and the operator is much more likely to be fatigued because of the mental workload before machine operations get more comfortable/less taxing for that operator.

[0026] Turning now to FIG. 3, and according to the present disclosure, a computerized method for adjusting machine capabilities 32 of a machine 10 in response to machine operating conditions 34, 42, wherein the computerized method is carried out by a controller, such as the controller 40, is exemplified. At step 82, the method includes collecting data corresponding to the machine operating conditions 34, 42 using the controller 40, wherein the data may include current machine health data 52, current operator skill level data 54, and current environmental factor data 56, for example.

[0027] The next step, step 84, includes comparing the machine operating conditions 34, 42 against stored metrics using the controller 40. For example, machine and implement inertial information may be measured and, if available, machine driveline data, to calculate machine performance and operator skill level to compare against nominal metrics. If the machine operation conditions 34, 42 are below the stored metrics, the machine capabilities 32 are decreased using the controller 40, at step 86. If the machine operation conditions 34, 42 are above the stored metrics, the machine capabilities 32 are increased using the controller 40, at step 88. Additionally or alternatively, feedback 62 may be provided to an operator, or other user, based on the machine operating conditions 34, 42. Machine capabilities may also be adjusted to increase advantages of better performance. For example, better operator performance may be exhibited by burning less fuel or from lower cycle times and the machine performance could be increased when that metric is lower than a threshold. Generally speaking, when metrics improve to a point, machine capabilities will be increased and when metrics degrade to a point, machine capabilities will be decreased.

Example: Protect Machine

[0028] Data may be compared to a wide range of metrics to set environmental and machine health adjustments 52 to machine performance limitations 32; if machine health 52, such as the temperature of certain components, (e.g., component overheat or need to warmup for optimal performance) or environmental factors 56, such as coefficient of traction degradation, is detected, then machine limitations/capabilities 32 may be increased or decreased throughout the workday, as deemed necessary.

[0029] Rental fleet owners may also require that renters slowly ramp up machine capabilities 32 to prevent machine abuse and damage through lack of proficiency when operating short-term rental equipment. Given current environmental limitations 56, machine health 52, and other factors, machine limitations/capabilities 32 may be displayed to the operator or owner via multiple methods, including in-cab displays, Bluetooth devices, websites and/or end of day reports, among many other potential means. For example, if the air cleaner is clogged, once it is cleaned, the machine may reduce the machine limitations/capabilities 32 for better machine performance.

[0030] According to additional examples, the following things could reduce machine abuse: requiring proper warm-up of the machine 10 prior to full-power operations, when approaching or having exceeded temperature limits, in component overspeed conditions, or as an operator approaches the hydraulic stops to prevent slamming the hydraulic cylinders, excess wheel slip, loss of control due to excess speed, among many other potential machine abuses, etc.

Example: Low Skilled Operator

[0031] It might be desirable to start a new operator at some reduced machine performance level by limiting the machine's maximum capabilities 32 in multiple areas. This avoids intimidating new operators with more speed and responsiveness than they are ready to utilize, and it provides a safe mode for infrequent operators, fuel delivery personnel, mechanics, truck drivers and initial machine delivery to the site. This provides a stable platform that adjusts machine performance as the operator's skill level increases, and increased machine performance as the operator improves their skills may be an incentive for operators to focus on their effectiveness.

[0032] Data will be compared to a wide range of operator skill metrics to set operator adjustments to machine limitations/capabilities 32 over time, matching operator skill level with machine capabilities 32 to prevent overburdening operators. If operator performance accumulates beyond the performance metrics, machine limitations may be relaxed, or limitations may be tightened when reduced operator performance is noted as compared against a nominal operator metrics. Machine controls can be adjusted to make it easier to control the machine 10, such as from reducing hydraulic/implement and steering response to make the machine 10 operate more smoothly for the less skilled operator.

[0033] If the machine capabilities 32 more closely match the skill level of the operator, operating the machine 10 will also be less fatiguing to that operator. The goal of the operator skill portion of this is to increase machine capabilities 32, slowly reducing limitations, as an operator becomes more proficient over time. This allows new operators to slowly build up confidence as the machine increase

capabilities **32**, such as implement and steering response and engine lug curve capabilities, among many other possibilities

[0034] An owner/dealer can set the initial capability levels above the normal default for expert operators on their site, allowing trusted operators to skip right to the maximum machine capabilities **32**. This will allow experienced operators to have more initial machine performance than a mechanic who gets the default since he only needs to move the machine **10** in to or out of a repair bay. The machine **10** will be much smoother and easier for a mechanic to operate with less than the maximum response to operator inputs.

[0035] Operator skill level will be calculated from the application cycle based on machine type and all available performance indicators. The operator inputs and estimations of how operator inputs could have been better controlled are calculated from nominal and expert operator samples for those application segments. Current operator skill levels and machine limitations may be displayed to the operator or owner via numerous methods, including in-cab displays, Bluetooth devices, websites and/or end of day reports, among many other potential means

[0036] The operator will also be given feedback on how to improve to the next level of machine capabilities **32** via the above potential methods. The operator could, perhaps, watch a 2-minute video on how an expert performs the application more rapidly, then they can work on the new technique, ultimately improving their productivity, unlocking more machine capabilities **32** and providing a better productivity workforce for the site owner without a dedicated operator mentor or trainer helping the operator regularly. A big potential benefit of this capability is a more engaged, less fatigued operator, which leads to higher overall efficiency and productivity without the additional cost of on-site trainer personnel.

Example: Fatigued Operator

[0037] Using all the above methods of collecting data, comparing data against metrics, and evaluating operator skill level, it is possible to detect temporary reductions in operator skills from fatigue, such as later in a shift, or after a particularly difficult set of tasks. This would only temporarily impose machine limitations to help make the machine **10** easier to operate and reduce further operator fatigue, improving overall machine productivity. The prior operator skill level can be quickly returned to after a break or next shift start when operator skill level has returned to normal levels.

[0038] Decreases in operator skill can result from fatigue late in a shift, and machine controls can be adjusted to make it easier to control the machine **10**, such as from reducing hydraulic and steering response to make the machine **10** operate more smoothly for the less skilled operator, as mentioned above, with machine capabilities **32** more closely matching the skill level of the operator. Operating the machine **10** will be less fatiguing to that operator, preventing further degradation from the extreme fatigue. Current operator skill levels, even from fatigue, and the associated machine limitations may be displayed to the operator or owner via many methods, including in-cab displays, Bluetooth devices, websites and/or end of day reports, among many other potential means. If categorizing the machine operating conditions as short-term conditions or long-term

conditions, the machine capabilities **32** may be reset after an operating shift in response to short-term conditions.

[0039] It should be understood that the above description is intended for illustrative purposes only, and is not intended to limit the scope of the present disclosure in any way. Thus, those skilled in the art will appreciate that other aspects of the disclosure can be obtained from a study of the drawings, the disclosure and the appended claims.

What is claimed is:

1. A computerized method for adjusting machine capabilities of a machine in response to machine operating conditions, wherein the computerized method is carried out by a controller, the computerized method comprising:

collecting data corresponding to the machine operating conditions using the controller, wherein the data includes current machine health data, current operator skill level data, and current environmental factor data; comparing the machine operating conditions against stored metrics using the controller;

decreasing the machine capabilities, using the controller, when the machine operating conditions are below the stored metrics; and

increasing machine capabilities, using the controller, when the machine operating conditions are above the stored metrics.

2. The computerized method of claim 1, wherein decreasing the machine capabilities includes decreasing at least one of machine component speed and machine component power.

3. The computerized method of claim 1, wherein increasing the machine capabilities includes increasing at least one of machine component speed and machine component power.

4. The computerized method of claim 3, wherein increasing the machine capabilities includes increasing the machine capabilities by an incremental percentage corresponding to the machine operating conditions.

5. The computerized method of claim 1, further including categorizing the machine operating conditions as short-term conditions or long-term conditions, wherein the machine capabilities are reset after an operating shift in response to short-term conditions.

6. The computerized method of claim 1, further including providing feedback to an operator based on the machine operating conditions.

7. The computerized method of claim 1, wherein the current machine health data is based on at least one of a temperature sensor, a pressure sensor, and a strain gauge.

8. The computerized method of claim 1, wherein the current operator skill level data is based on at least one of payload production, fuel efficiency, bucket load time, bucket fill time, and near misses.

9. The computerized method of claim 1, wherein the current environmental factor data is based on at least one of wind, water, humidity, temperature, movement, and pressure.

10. The computerized method of claim 1, wherein an operator of the machine is located remote from the machine.

11. A machine, comprising:

a machine frame;

ground-engaging elements supported on the machine frame;

an engine supported on the machine frame and drivably connected to the ground-engaging elements; and

a controller supported on the machine frame and carrying out the following:

collecting data corresponding to machine operating conditions using the controller, wherein the data includes current machine health data, current operator skill level data, and current environmental factor data;

comparing the machine operating conditions against stored metrics using the controller;

decreasing machine capabilities, using the controller, when the machine operating conditions are below the stored metrics; and

increasing machine capabilities, using the controller, when the machine operating conditions are above the stored metrics.

12. The method of claim **11**, wherein decreasing the machine capabilities includes decreasing at least one of machine component speed and machine component power.

13. The machine of claim **11**, wherein increasing the machine capabilities includes increasing at least one of machine component speed and machine component power.

14. The method of claim **13**, wherein increasing the machine capabilities includes increasing the machine capabilities by an incremental percentage corresponding to the machine operating conditions.

15. The method of claim **11**, wherein the current machine health data is based on at least one of a temperature sensor, a pressure sensor, and a strain gauge.

16. The method of claim **11**, wherein the current operator skill level data is based on at least one of payload production, fuel efficiency, bucket load time, bucket fill time, and near misses.

17. The method of claim **11**, wherein the current environmental factor data is based on at least one of wind, water, humidity, temperature, movement, and pressure.

18. A computer readable medium including non-transitory computer readable code comprising instructions for:

collecting data corresponding to machine operating conditions, wherein the data includes current machine health data, current operator skill level data, and current environmental factor data;

comparing the machine operating conditions against stored metrics;

decreasing machine capabilities when the machine operating conditions are below the stored metrics; and
increasing machine capabilities when the machine operating conditions are above the stored metrics.

19. The computer readable medium of claim **18**, wherein the computer readable code comprises instructions for decreasing at least one of machine component speed and machine component power.

20. The computer readable medium of claim **18**, wherein the computer readable code comprises instructions for decreasing at least one of machine component speed and machine component power.

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