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Machine, system and method for road construction

Abstract

A method of building a road is disclosed. The method may include moving a machine over a surface on which the road is to be built, and generating a signal indicative of a texture of the surface during movement of the machine over the surface. The method may also include detecting a location of the texture on the surface, and determining, using a specially programmed processor, an amount of a material to be applied to the location of the texture on the surface based on the signal. The method may further include automatically applying the amount of material to the location of the texture on the surface to build the road.

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Background/Summary

RELATED APPLICATIONS (1) This application is based on and claims the benefit of priority from U.S. Provisional Application No. 63/323,803 that was filed on Mar. 25, 2022, the contents of which are expressly incorporated herein by reference.

TECHNICAL FIELD
(1) The present disclosure relates generally to road construction and, more particularly, to a machine, system and method for constructing a road.
BACKGROUND
(2) For the purposes of this disclosure, a road can be considered a durable surface (e.g., a route, way, path, drive, street, lane, lot, or similar thoroughfare or park) that has been prepared on land or over water to support any one or more of various types of traffic (e.g., vehicular traffic, pedestrian traffic, railway traffic, aircraft ground traffic, bicycle traffic, etc.). While roads can be constructed in a variety of different ways, most of these ways involve the application of a specialized material to an existing or newly prepared surface.
(3) Asphalt is one example of a material specially prepared for use in building roads. Asphalt, also known as bitumen, is a binder used to adhere filler or reinforcement (e.g., sand, aggregate, etc.) together and to the underlying surface. An asphalt road is durable and flexible, allowing expansion and contraction without damage. The asphalt can be asphalt cement (AC), polymer modified asphalt (PMA), cutback, and emulsions. Other materials (e.g., primers, hardeners, additives, etc.) may be used together with asphalt when building roads.
(4) Many different methods exist for applying asphalt (and/or other building materials) to an underlying surface during the making of a road. One method is known as Chip Sealing. During the

Chip Sealing process, an asphalt mixture is prepared and loaded into a spray truck (e.g., the Blacktopper Centennial Distributor by E. D. Etnyre & Co. or the Asphalt Distributor BC-502 by Bearcat Manufacturing). The spray truck is equipped with a vessel that holds the emulsion, and a spray bar at a trailing end of the vessel that extends transversely across a width of the road. Any number of nozzles are mounted to the spray bar. An engine-driven pump presses the asphalt mixture from the vessel through the spray bar and nozzles and onto the underlying surface behind the spray truck, while the spray truck travels along a length of the surface. In some applications, another machine follows behind the spray truck and applies aggregate over the layer of asphalt, while yet another machine compacts the aggregate into the asphalt.

(5) During the building of a road, it is possible to apply an incorrect amount of asphalt. When too much asphalt is applied, the asphalt can flush up through the aggregate and form a smooth upper surface that is slippery. An excessive amount of asphalt is also wasteful and expensive. When too little asphalt is applied, the aggregate may not stick to the road and can cause damage to vehicles traveling the road as the aggregate unravels from the underlying surface.

(6) Typically, the asphalt is applied by the nozzles of the spray truck at a predetermined rate (e.g., a set volumetric amount per area of roadway) based on a plan generated in advance for a particular road. The road plan is manually prepared by an engineer based on average measurements previously captured over a broad stretch of the road (e.g., over an entire length of the road being constructed). The measurements can include an average texture of the underlying surface.

(7) The rate of asphalt application required by the plan is electronically transferred into a distribution controller mounted on the spray truck. The controller monitors a travel speed of the truck along the road, and responsively adjusts operation of the pump such that an actual rate of discharge from the nozzles provides the planned rate along the length of the road.

(8) While the conventional machine, control system and method discussed above may be adequate for some applications, it can also be less than optimal. For example, relying on only an average measurement of texture to determine the application rate for the entire road may result in over application in some areas and under application in other areas. In addition, the average texture measurements typically used to generate the plan may not consider all factors affecting performance of the road. Further, the conventional process for manually taking the texture measurements (e.g., using sand circles) and thereafter developing and implementing the plan may be slow, labor-intensive and expensive.

(9) The disclosed machine, system and processes are directed to overcoming one or more of the problems set forth above and/or other problems of the prior art.

SUMMARY

(10) In one aspect, the present disclosure is directed to a method of building a road. The method may include moving a machine over a surface on which the road is to be built, and generating a signal indicative of a texture of the surface during movement of the machine over the surface. The method may also include detecting a location of the texture on the surface, and determining, using a specially programmed processor, an amount of a material to be applied to the location of the texture on the surface based on the signal. The method may further include automatically applying the amount of material to the location of the texture on the surface to build the road.

(11) In another aspect, the present disclosure is directed to another method of building a road. This method may include moving a machine over a surface on which the road is to be built and, during movement of the machine over the surface, using at least one sensor mounted on the machine to generate signals indicative of textures of the surface. The method may also include using a locating device mounted on the machine to detect locations of the textures on the surface, and using a specially programmed processor to determine amounts of a material to be applied to the locations of the textures based on the signal. The method may further include automatically causing the machine to apply the amounts of the material to the locations of the textures on the surface to build the road during the moving of the machine over the surface.

(12) In yet another aspect, the present disclosure is directed to a road building machine. The road building machine may include a vehicle, and a distribution arrangement mounted to the vehicle and configured to distribute a material on to a surface as the vehicle moves over the surface. The road building machine may also include at least one sensor mounted to the vehicle and configured to generate a signal indicative of a texture of the surface during movement of the vehicle over the surface, a locating device configured to detect a location of the texture, and a controller in communication with the distribution arrangement, the at least one sensor, and the locating device. The controller may be specially programmed to determine an amount of the material to be applied to the location of the texture based on the signal, and to automatically cause the distribution arrangement to distribute the amount of the material on to the surface at the location of the texture as the vehicle moves over the surface.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** is a diagrammatic illustration of example machines that may be used to build at least a portion of a road;

(2) FIG. **2** is a diagrammatic illustration of an example system that may be used to control the machine(s) of FIG. **1**; and

(3) FIG. **3** is a flowchart of an example method that may be implemented by the system of FIG. **2** using the machine(s) of FIG. **1**.

DETAILED DESCRIPTION

(4) The terms “about” and/or “generally” as used herein serve to reasonably encompass or describe minor variations in numerical values measured by instrumental analysis or as a result of sample handling. Such minor variations may be considered to be “within engineering tolerances” and in the order of plus or minus 0% to 10%, plus or minus 0% to 5%, or plus or minus 0% to 1%, of the numerical values.

(5) The term “substantially” as used herein refers to a majority of, or mostly, as in at least about 50%, 60%, 70%, 80%, 90%, 95%, 96%, 97%, 98%, 99%, 99.5%, 99.9%, 99.99%, or at least about 99.999% or more.

(6) FIG. **1** illustrates a work environment **10**, in which one or more machines **12** are performing a road-building operation. It should be noted that, while building of a new road **14** will be discussed in detail below, the concepts disclosed in this specification may be equally applicable to maintenance, rehabilitation and/or preservation of an existing road **14**. As will also be explained in more detail below, a location, orientation, speed and/or trajectory of machine(s) **12** may be tracked (e.g., by a network of satellites **16**) during the road-building operations.

(7) Machine(s) **12** may be configured to apply one or more materials to an existing or newly prepared surface **18** to form, build up, treat and/or repair at least a portion of road **14**. The material may include, for example, an asphalt material, an asphalt mixture (e.g., including an asphalt emulsion, liquid, or slurry and a diluent, additives, fillers, binders, polymers, catalysts, etc.), concrete, a concrete mixture, a priming material, a cure-enhancing material, a strengthening material, a dust-controlling and/or stabilizing material, aggregate, and/or another road material known in the art. It should be noted that, while machine(s) **12** will be described in detail as land-based machines, any one or more of the disclosed machine(s) **12** could embody a non-land based machine (e.g., an aerial drone) configured to perform the same or similar operations, if desired. It is also contemplated that the configurations of and/or operations disclosed as being performed by a single machine **12** could alternatively be distributed among multiple different machines **12**. Likewise, it is contemplated that the configurations of and/or operations disclosed as being performed by multiple different machines **12** could alternatively be integrated into a lesser number

of machines (e.g., one machine) **12**.

(8) FIG. **1** illustrates multiple machines **12** cooperating as a convoy to build up existing surface **18** and form new road **14**. Various convoy arrangements are envisioned that together may form new road **14**. In one specific example, the convoy consists of one or more distributors (“distributor”—left-most machine **12** illustrated in FIG. **1**), followed by one or more aggregate spreaders (“spreader”) that are supplied with aggregate by any number of different haul trucks, followed by one or more compactors (right-most machine **12** illustrated in FIG. **1**). It is contemplated that the convoy could additionally include any number of surface-conditioning machines (e.g., milling machines, reclaiming machines, shaping machines, patching machines, etc.—not shown) that lead the distributor and condition surface **18** prior to the application of new material.

(9) It should be noted that, while the remainder of this disclosure will focus on the distributor introduced above, many (e.g., some or all) of the disclosed concepts may be applicable to one or more other machine(s) **12** of the road-building convoy depicted in FIG. **1**.

(10) The distributor may include components that cooperate to apply one or more materials to surface **18**. These components may include, among other things, a vehicle **20**, one or more vessel(s) **22** supported by vehicle **20** and configured to hold the material(s), and a distribution arrangement (“arrangement”) **24** configured to receive the material(s) from vessel **22** and distribute (e.g., spray) the material(s) onto surface **18** and/or road **14**.

(11) Vehicle **20** may, itself, be an assembly of components that supports and/or powers the other components/systems of machine **12**. In the disclosed embodiment, these components may include a chassis, a power source mounted to the chassis, a drivetrain that is operatively connected to and driven by the power source, and one or more propulsion devices powered by the drivetrain. The power source may include any source known in the art for powering a vehicle. Example sources include an engine (e.g., a gasoline engine, a diesel engine, a gaseous fuel-powered engine, etc.), a battery, or a hybrid engine/battery configuration. Example drivetrains include a transmission, a driveline, a final drive, one or more electric motors, and/or a hybrid transmission/final drive or electric motor configuration. Example propulsion devices include wheels, tracks, feet, fans, jets, blades, and/or propellers.

(12) The chassis of vehicle **20** may be configured to support vessel(s) **22** and distribution arrangement **24**. In the disclosed embodiment, only a single vessel **22** is shown as being supported by the chassis. However, in some applications, multiple different materials may need to be separately discharged, simultaneously discharged and/or discharged together onto surface **18** and/or road **14**. In these embodiments, more than one vessel **22** may be mounted to the chassis. For example, as shown in FIG. **2**, a first vessel **22***a* may be configured to hold a first material (e.g., a priming emulsion), and a second vessel **22***a* may be configured to hold a second material (e.g., an asphalt mixture). In some embodiments, a catalyst (e.g., a hardener that reacts with the asphalt mixture) may be held within an additional third vessel (not shown). Each of these vessel(s) **22** may include an inlet to receive the material, an outlet to discharge the material, and any number of conditioning devices (e.g., mixers, agitators, heaters, coolers, recirculation circuits, sensors, valves, conduits, additive injectors, etc.) **23** that serve to condition the material inside of vessel(s) **22**.

(13) In the example of FIG. **2**, arrangement **24** may include components mounted to the chassis of vehicle **20** that cooperate to selectively discharge the material from vessel(s) **22** onto surface **18** and/or road **14**. The components may include, among other things, one or more pumps **26**, one or more spray bars **28**, and any number of nozzles **30**.

(14) Each pump **26** may be controlled to draw material from a corresponding vessel or vessels **22** and direct the material under pressure to a corresponding one or more spray bars **28**. In multi-pump embodiments, pumps **26** may be arranged in parallel and independently controlled to provide a different flow rate and/or pressure of material to corresponding spray bars **28**. Each pump **26** may be mechanically, hydraulically, pneumatically, and/or electrically driven by the power source of vehicle **20** (or another source, for example a chassis-mounted auxiliary power unit—not shown). In

some embodiments, one or more of pumps **26** can be regulated somewhat or completely independent of the vehicle power source (e.g., an electrically powered pump may operate independent of speed and/or torque outputs of the power source) to provide a variable (e.g., infinitely variable) flowrate and/or pressure. In these embodiments, pumps **26** may be rate- and/or pressure-regulated via a command directed to the corresponding pumps and/or associated motors (not shown) driving the pumps **26**.

(15) Spray bar(s) **28** may be arranged lengthwise across a partial or full width of vehicle **20** (e.g., at a leading end, at a trailing end, and/or at a point between the leading and trailing ends, relative to a normal or forward travel direction represented by an arrow **25** illustrated in FIG. **2**). Spray bars **28** may be fluidly connected to receive the pressurized material from pump(s) **26**. If multiple spray bars **28** are included, they may be arranged in series or in parallel and configured to conduct the same or different materials to their associated nozzle(s) **30**.

(16) In the disclosed embodiment shown in FIG. **2**, a first spray bar **28***a* is fluidly connected to vessel **22***a* and located at the leading end or a midpoint of vehicle **20** (e.g., in front of front tires or between front and rear tires). Spray bar **28***a* may be configured to conduct the priming emulsion from vessel **22***a* to the nozzles **30** associated with spray bar **28***a*.

(17) In the same example of FIG. **2**, at least one spray bar **28** (e.g., a second spray bar **28***b* and a third spray bar **28***c*) may be fluidly connected to vessel **22***b* and located at the trailing end of vehicle **20** (e.g., behind the rear tires). Spray bars **28***b*, **28***c* are shown as being both configured to conduct an asphalt mixture from vessel **22***b* to the nozzles **30** associated with spray bars **28***b*, **28***c*. A distance between spray bar **28***a* and spray bars **28***b*, **28***c* may be selected to allow the priming material sprayed by nozzles **30** of spray bar **28***a* to penetrate surface **18** and/or to attain another prerequisite (e.g., to partially or fully dry) before the asphalt mixture is sprayed onto the priming material by nozzles **30** of spray bars **28***b*, **28***c*.

(18) In the example of FIG. **2**, multiple spray bars **28** are utilized at the trailing end of vehicle **20** for several reasons. First, a greater volume of material may be discharged via utilization of multiple spray bars **28**. Second, a greater flexibility in control over the spraying of the material may be available. For example, each of spray bars **28***a*, **28***c* could be supplied with material via a single pump **26** and have a similar flowrate and/or pressure or be supplied with material via separate pumps **26** that have different flowrates and/or pressures. In either embodiment, spray bar **28***b* could be utilized alone, spray bar **28***c* could be used alone, or spray bars **28***b* and **28***c* could be activated together to provide an even greater range of flow rates and/or pressures.

(19) It should be noted that spray bars **28***b*, **28***c* could alternatively be associated with different vessels **22** and be configured to conduct different materials to their corresponding nozzles **30**, if desired. For example, spray bar **28***b* may conduct the asphalt mixture from vessel **22***b*, while spray bar **28***c* may trail spray bar **28***a* and conduct a different material (e.g., a chemical catalyst, heated air, etc.) that affects the way (e.g., a speed) that the asphalt mixture cures and/or hardens (“bricks”). The cure-enhancing material may be sprayed onto surface **18** at the same time as or after the asphalt material is sprayed. For example, the material from spray bar **28***b* may pass through the material spraying from spray bar **28***c*, such that the two materials mix in the air prior to coating surface **18** and/or mix just as they coat surface **18**.

(20) In some embodiments, when multiple spray bars **28** are included, each spray bar **28** may discharge material to a separate segment across the width of vehicle **20** or to overlapping or common segments. For example, spray bars **28** may be arranged end-to-end or in adjacent (e.g., overlapping) rows. In one particular embodiment, a first spray bar **28** extends across the entire width, while an additional one or more spray bars **28** overlap the first spray bar **28** and extends only across a partial width (e.g., only across wheel path or seam areas).

(21) Each spray bar **28** may function as a manifold for the corresponding nozzles **30** fluidly receiving material therefrom. In one particular embodiment, forty-eight nozzles **30** are distributed along the length of each spray bar **28** and across the width of vehicle **20**. In this embodiment, a

length of each spray bar **28** is sixteen feet, such that vehicle **20** has a nozzle density of three nozzles per foot. It is contemplated, however, that the number of nozzles **30** and/or the length of each spray bar **28** could be different.

(22) Any type, size, and/or configuration of nozzle **30** may be utilized in conjunction with arrangement **24**. In some embodiments, multiple types/sizes, and/or configurations of nozzles **30** may be utilized at the same time. It is also contemplated that nozzles **30** may be selectively swapped out for nozzles **30** of different types, sizes and/or configurations to provide a different rate and/or profile of material application.

(23) Nozzles **30** may be independently regulated, regulated all together, or regulated in groups, as desired. For example, one or more valves **32** may be associated with each spray bar **28**, each nozzle **30**, or different groupings of nozzles **30**. Valve **32** may be any type of valve known in the art for regulating a flow of pressurized material. In the example of FIG. **2**, valve **32** is a poppet-style valve associated separately with each nozzle **30**, and the flow/pressure of material supplied to each nozzle **30** is regulated via operation of the corresponding pump and/or another valve (e.g., a butterfly valve) associated with spray bar **28**. Each nozzle **30** may be controlled to spray a desired amount of material within a given period of time based on the pressure of the material within spray bar **28**, how often the poppit valve is opened, how far the poppit valve is opened, and/or how long the poppit valve remains open. When nozzles **30** are regulated in groups, an actuator **34** (e.g., a pneumatic cylinder, an electric solenoid, a hydraulic pilot, etc.) may be associated with multiple valves **32** to synchronize their openings/closings.

(24) In some embodiments, nozzles **30** may be dynamically adjustable. For example, nozzles **30** may be rotated and/or shifted (e.g., side-to-side) to adjust a spray angle, spray area, spray orientation, and/or spray overlap. In these embodiments, an additional rotary and/or linear actuator (not shown) may be associated with each nozzle **30** or grouping of nozzles **30**.

(25) It is contemplated that spray bars **28**, together with their associated nozzles **30**, may also or alternatively be dynamically adjustable. For example, spray bars **28** may be extended, folded, tilted, and/or separately deployed to adjust a width, depth, and/or overlap of spray areas. Any number/type of actuators and any configuration of motions platforms (e.g., hinges, sliding carriages, linkages, etc.) may be used to facilitate these motions.

(26) In some applications (e.g., the application shown in FIG. **1**), vehicle **20** may also include an operator station housing informational devices **36** (shown in FIG. **2**) and/or control devices **38** usable by a human operator to regulate vehicle **20** and/or distribution arrangement **24**. Example informational devices **36** may include, among other things, a display screen, a speaker, a visual indicator (e.g., a light indicator, a dial indicator, a level indicator, etc.), a tactile device (e.g., a seat rumbler or stick vibrator), etc. Example control devices **38** may include, among other things, a joystick, a steering wheel, a pedal, a switch, a button (e.g., a virtual button on a display screen or a physical button), a lever, a keyboard, a mouse, a key, etc. Information about machine **12** may be relayed to the operator via informational devices **36**, and control instructions or commands for machine **12** may be received from the operator via control devices **38**.

(27) It is contemplated that the operator station of machine **12** may be omitted, in some applications. For example, machine **12** could be at least partially controlled in a remote and/or autonomous manner. In these applications, the operator station may be minimized, located remotely (e.g., offboard vehicle **20**), and/or completely omitted. In other applications, machine **12** could embody a trailer towed behind another vehicle. In this latter example, the operator station may be mounted on the other vehicle and used to monitor and control operations occurring on and/or performed by the trailer.

(28) As also shown in FIG. **2**, a control system (“system”) **40** may be associated with machine **12** and configured to regulate one or more operations of machine **12** in an automated or semi-automated manner. For example, system **40** may be configured to generate a plan for building road **14**, and also regulate distribution of the road material(s) contained in vessel(s) **22** onto surface **18**

according to the plan for road **14** (e.g., while machine **12** travels along surface **18**). As will be explained in more detail below, the plan may include segmentation of surface **18** into multiple separate areas that require different application rates (e.g., material layer thicknesses) and/or types of road material(s). System **40** (e.g., a controller **44** of system **40**) may interact with any number of acquisition devices to acquire information about surface **18**, the material(s) to be applied and/or being applied to surface **18**, environment **10**, and specifications for road **14**. System **40** (e.g., controller **44**) may receive, generate and/or modify the plan for road **14** based on the acquired information. System **40** (e.g., controller **44**) may then regulate any number of control devices to ensure that machine **12** distributes the material(s) according to the plan.

(29) Controller **44** may include, among other things, one or more processors, any number of input/output ("I/O") devices, and one or more memories for storing programs and data. The programs may include, for example, any number of planning and/or paving apps and an operating system.

(30) Each of the processor(s) may be a single or multi-core processor configured with virtual processing technologies, and specially programmed with logic to simultaneously execute and control any number of operations. The processor(s) may be configured to implement virtual machine technologies, machine learning technologies, artificial intelligence, neural networks, machine logic, and/or other known technologies to execute, control, run, manipulate, analyze and/or store any number of software modules, applications, programs, etc. In addition, in some embodiments, the processor(s) may include one or more specialized hardware, software, and/or firmware modules (not shown) specially configured with particular circuitry, instructions, algorithms, and/or data to perform functions of the disclosed methods. It is appreciated that other types of processor arrangements could be implemented that provide for the capabilities disclosed herein.

(31) The memory can be a volatile or non-volatile, magnetic, semiconductor, tape, optical, removable, non-removable, or other type of storage device or tangible and/or non-transitory computer-readable medium that stores one or more executable programs, such as analysis, planning and/or paving apps and the operating system. Common forms of non-transitory media include, for example, a flash drive, a flexible disk, a hard disk, a solid state drive, magnetic tape or other magnetic data storage medium, a CD-ROM or other optical data storage medium, any physical medium with patterns of holes, a RAM, a PROM, an EPROM, a FLASH-EPROM or other flash memory, NVRAM, a cache, a register or other memory chip or cartridge, and networked versions of the same.

(32) The memory may store instructions that enable the processor(s) to execute one or more applications, such as the analysis, planning and/or paving apps, the operating system, and any other type of application or software known to be available on computer systems. Alternatively or additionally, the instructions, application programs, etc. can be stored in an internal and/or external database (e.g., a cloud storage system—not shown) that is in direct communication with controller **44**, such as one or more databases **46** or memories accessible via one or more networks (not shown). The memory can include one or more memory devices that store data and instructions used to perform one or more features of the disclosed embodiments. The memory can also include any combination of one or more databases controlled by memory controller devices (e.g., servers, etc.) or software, such as document management systems, Microsoft SQL databases, SharePoint databases, Oracle™ databases, Sybase™ databases, or other relational databases.

(33) In some embodiments, controller **44** is communicatively connected to one or more remote memory devices (e.g., remote databases—not shown) through a network (not shown). The remote memory devices can be configured to store information that controller **44** can access and/or manage. By way of example, the remote memory devices could be document management systems, government databases (e.g., a geographic information system—GIS, a spectral signature library such as the USGS library, digital elevation models, land cover/use maps, etc.), and private libraries

and databases (e.g., Microsoft SQL database, SharePoint databases, Oracle databases, Sybase databases, Cassandra, HBase, or other relational or non-relational databases or regular files). Systems and methods consistent with disclosed embodiments, however, are not limited to separate databases or even to the use of a database.

(34) The programs may include one or more software or firmware modules causing the processor(s) to perform one or more functions of the disclosed embodiments. Moreover, the processor(s) can execute one or more programs located remotely from controller **44**. For example, controller **44** can access one or more remote programs that, when executed, perform functions related to disclosed embodiments. In some embodiments, the programs stored in the memory and executed by the processor(s) can include one or more of the analysis, planning, and/or paving apps and the operating system. The apps may cause the processor(s) to perform one or more functions of the disclosed methods.

(35) The operating system may perform known operating system functions when executed by one or more processors of controller **44**. By way of example, the operating system may include Microsoft Windows, Unix, Linux, OSX, IOS, Raspberry Pi OS (e.g., Rapbian), Android, or another type of the operating system. Accordingly, disclosed embodiments can operate and function with computer systems running any type of the operating system.

(36) The I/O devices may include one or more interfaces (e.g., informational and/or control devices **36**, **38**) for receiving signals or input from a user (e.g., an operator of machine **12**, an observing technician, a remote engineer, etc.), and for providing signals or output to the user and/or machine **12** that allow road **14** to be built.

(37) The analysis, planning and/or paving apps may cause controller **44** to perform methods related to generating, receiving, processing, analyzing, storing, and/or transmitting data in association with operation of machine **12** and corresponding analysis/planning/paving of road **14**. For example, the apps may be able to configure controller **44** to perform operations including: receiving instructions from an engineer of road **14** regarding specifications, materials to be used, desired characteristics, and/or desired performance of road **14**; capturing sensory data associated with machine **12**, surface **18**, the environment, and/or the materials; receiving control instructions from the operator and/or the user of machine **12** during operation; processing the instructions, specifications, characteristics, performance criteria, sensory data and control instructions; generating one or more possible plans for building road **14**; analyzing and/or optimizing the plans; providing recommendations of one or more plans; controlling machine **12** to build road **14** via a recommended and/or selected plan; analyzing the building of road **14** in real or near-real time; and/or providing feedback and adjustments to machine **12** for improving current and/or future building operations.

(38) The input and output devices useable by controller **44** during planning and/or building of road **14** may be standalone devices or devices that are embedded within, mounted on, and/or otherwise associated with machine **12**. As shown in FIG. **2**, the input devices may include, among other things, one or more location input devices **48**, one or more environment input devices **50**, one or more (e.g., a plurality of) surface input devices **52**, one or more machine input devices **54**, and one or more distribution input devices **56**.

(39) Location input device(s) **48** may include any number of mechanisms configured to generate location data indicative of a geographical position, orientation, heading, speed, and/or acceleration of machine **12** relative to a local reference point, a coordinate system associated with environment **10**, a coordinate system associated with Earth, or any other type of 2-D or 3-D coordinate system.

(40) In one application, an example location input device **48** embodies an electronic receiver configured to communicate with satellite(s) **16** (referring to FIG. **1**) or a local radio or laser transmitting system (not shown) and used to determine a relative geographical location of itself. This location input device **48** may receive and analyze high-frequency, low-power radio or laser signals from multiple locations to triangulate a relative 3-D geographical position and orientation. In some embodiments, location input device **48** may also be configured to determine a location

and/or orientation of a particular part of machine **12** (e.g., of distribution arrangement **24**, each spray bar **28**, each nozzle **30**, each area being sprayed with material, each device **52**, each area being scanned by each device **52**, etc.). Based on signals generated by location input device(s) **48** (i.e., based on the location data) and based on known kinematics of machine **12**, controller **44** may be able to determine in real or near-real time the position, heading, travel speed, acceleration, and/or orientation of machine **12** and/or any system component mounted to machine **12**, relative to one or more areas of surface **18**.

(41) In another application, an example location input device **48** embodies one or more powertrain sensors (e.g., an odometer, a speedometer, a tachometer, a transmission or final drive sensor, a steering sensor, etc.) associated with machine **12** and configured to track a distance, speed, acceleration, trajectory, and/or travel time along surface **18** from a known starting point. Based on signals generated by this/these input device(s) **48**, controller **44** may again be able determine in real or near-real time the position, heading, travel speed, acceleration, and orientation of machine **12** and/or system component relative to the area(s) of surface **18**.

(42) In yet another application, an example location input device **48** embodies a camera mounted to machine **12** and configured to capture images of surface **18** and/or the environment around surface **18**. In this example, controller **44** may be programmed with image recognition software that allows controller **44** to determine the position, heading, travel speed, acceleration and/or orientation of machine **12** and/or system component relative to the area(s) of surface **18**.

(43) Environment input device(s) **50** may include any number of devices configured to generate environmental data indicative of an environmental condition affecting distribution, curing, and/or performance of the material used to build road **14**. In one application, an example environment input device **50** embodies a camera mounted to machine **12** and configured to capture images of the environment around surface **18**. In this example, controller **44** may be programmed with image recognition software and/or algorithms that allow controller **44** to determine geological features **57** (shown in FIG. **1**) on and/or around surface **18** based on recognized images. These features may include, for example, a grade in a length direction of surface **18**, a contour (e.g., wheel ruts, potholes, crowning, etc.) in a width direction of surface **18**, a feature (e.g., a berm, cliff, tree, mountain, building, etc.) that casts a shadow over surface **18**, a feature (e.g., a body of water, a ravine, etc.) that generates humidity or lowers air temperature around surface **18**, etc.

(44) In another application, an example environmental input device **50** includes a sensor (e.g., an accelerometer, a light sensor, an acoustic sensor, etc.) that is configured to gather environmental data (e.g., grade, sun exposure or shadowing intensity, surface contours or roughness, etc.) associated with surface **18** and/or the environment surrounding surface **18** during travel of machine **12** along surface **18**.

(45) Surface input device(s) **52** may include any number of devices configured to generate surface data indicative of a condition of surface **18** affecting how well the material to be applied by machine **12** will adhere to surface **18** and/or perform over the life of road **14**. In the disclosed embodiment, multiple input devices **52** are illustrated in FIGS. **1** and **2** as being arrayed across the leading end of vehicle **20**. In this embodiment, the number of input devices **52** may be equal to the number of independently controllable groupings of nozzles **30** across the width of vehicle **20**. For example, for the configuration of vehicle **20** described above that is equipped with sixteen controllable subsets of nozzles **30**, sixteen independent input devices **52** may be located to separately scan one-foot segments across the width of vehicle **20** at the leading end. For greater scan resolution and material application control, vehicle **20** may be equipped with the same number of input devices **52** as the number of independently controllable nozzles **30** (e.g., forty-eight input devices **52** to match forty-eight nozzles **30**, each having a spray width of four inches).

(46) It should be noted that, while input devices **52** are shown and described as being located at the leading end of vehicle **20** (e.g., in front of the front tires), input devices **52** may be located closer to spray bar(s) **28** (e.g., behind the front tires), if desired. A further distance between input devices **52**

and spray bar(s) **28** may result in a cleaner environment for input devices **52**. However, the greater distance may also result in a greater amount of time elapsed since a particular segment of surface **18** is scanned and subsequently sprayed with material. As will be explained in more detail below, this time should be accounted for when using input devices **52** and nozzles **30** in a real or near-real time application.

(47) In one application, an example surface input device **52** includes a texture sensor configured to generate a signal indicative of a texture of surface **18**. The texture sensor may embody a LIDAR sensor (e.g., using a point cloud generator), a RADAR sensor, a sound (e.g., ultrasound) sensor, an inductive sensor (e.g., using a resonant inductive circuit), a capacitive sensor (e.g., using an oscillating signal generator), a laser sensor (e.g., using time-of-flight information), or another type of sensor that generates a signal indicative of a height from the sensor to uppermost boundaries of surface **18**. In this application, a change and/or a change rate in the height (i.e., a relative difference in terrain level) detected by input device(s) **52** may correspond with a texture at a specific location on surface **18**.

(48) In another application, an example surface input device **52** may include an accelerometer or acoustic sensor configured to generate signals indicative of vibrations induced within machine **12** (e.g., via the tires of vehicle **20**) because of varying textures of surface **18**. These vibrations (e.g., accelerations and/or noise traces) may then be related by controller **44** to relative differences in terrain level.

(49) In yet another application, an example surface input device **52** may include a camera configured to capture images of the uppermost boundaries discussed above. Controller **44** may then be configured to directly measure the relative differences in terrain level from the images.

(50) Machine input device(s) **54** may include any number of devices configured to generate data indicative of operating condition(s) of machine **12** that affect planning, monitoring and/or controlling of the road building process. These devices may include any number of sensors configured to detect a powertrain operation (e.g., an engine rpm, a transmission gear or rpm, a hydrostatic pressure of a power-takeoff driving pump **26**, a rotational speed of a tire or final drive, a steering angle, a speed of surface **18** passing below machine **12**, etc.).

(51) Distribution input device(s) **56** may include any number of devices configured to generate data indicative of operating condition(s) of distribution arrangement **24** that affect monitoring and/or controlling of the road building process. These devices may include sensors configured to detect a parameter associated with the material in vessel **22**, a parameter associated with operation of pump **26**, a parameter associated with spray bar(s) **28**, a parameter associated with nozzles **30**, etc. and to generate corresponding signals. The parameters may include, among other things, an amount of material remaining in vessel **22**; a temperature and/or viscosity of the material; an rpm, a displacement, a flowrate and/or a pressure of pump **26**; a temperature, a flowrate and/or a pressure inside of spray bar(s) **28**; a temperature, a flowrate, a pressure, a spray area, settings (e.g., diameters, angles, orientations, etc.), etc. of nozzles **30**; an activation status of any of these and other components (e.g., of valves **32** and/or actuators **34**); and other parameters known in the art.

(52) In some embodiments one or more additional sensors **58** may be associated with the convoy of machines **12** illustrated in FIG. **1**—but not mounted on or otherwise associated with the same machine (e.g., not associated with the distributor) **12** discussed above. For example, a material (e.g., aggregate) sensor **58** may be associated with the machine(s) **12** trailing behind the distributor. In one example, sensor **58** is associated with the aggregate spreader. In another example, sensor **58** is associated with a haul truck that delivers aggregate to the spreader. In either situation, sensor **58** may be configured to generate one or more signals indicative of a shape, size, and/or amount of aggregate delivered to and/or spread by the spreader. Sensor **58** may be, for example, a camera, a LIDAR sensor, a RADAR sensor, a laser sensor, or another type of sensor known in the art. The signals may be directed (e.g., wirelessly) to controller **44** for further processing.

(53) The signals generated by devices **23**, **36**, **38**, **48**, **50**, **52**, **54**, **56** and **58** may be indexed

according to time and/or location, and used for planning, road building, and/or reporting purposes. The signals may be generated during traversal of surface **18** by a machine **12** (e.g., the distributor or another machine **12**) before the application of any material by the distributor or another machine **12**; during the application of material by the distributor or another machine **12** in real or near-real time; and/or after the application of material by the distributor or another machine **12**. The signals may be directed (e.g., wirelessly or via wired means) to controller **44** for processing.

(54) It should be noted that similar devices may be used to generate the same signals for different purposes and/or different signals for different purposes. In these situations, it is contemplated that system **40** could include multiple separate devices that are similar or the same, or that the different functionalities could be performed by common devices. It is also contemplated that instead of, or in addition to, measuring all of the different parameters discussed above, one or more of these parameters may be pulled from a local or remote database (e.g., from database **46**) based on the detected and/or known position and/or orientation of machine **12**. For example, geographical data, climate data, weather data, historical traffic data, previous road deterioration and/or performance data, and other related parameters could have been measured, modeled, and/or calculated at a previous time and stored within database **46** that is accessible by controller **44**. In this way, arrangement **24** may be simplified and/or produced at a lower cost.

(55) Any number of output devices may be under the regulation of controller **44** to affect data collection, planning, and/or operation of machine **12** and arrangement **24**. These devices may include, among other things, the conditioning devices **23** associated with vessel **22** and/or distribution bar(s) **28**; pumps **26**; nozzles **30**; valves **32** and/or other metering devices disposed at various locations within arrangement **24**; actuators **34**; the powertrain (e.g., engine fuel regulators, transmission gear regulators, steering actuators, etc.) of vehicle **20**; etc.

(56) In some embodiments, the input and/or output devices may, themselves, include one or more processors (e.g., a programmable logic control (PLC), a computer numeric controller (CNC), etc.), a memory, and/or a transceiver. When these devices are equipped with a dedicated processor and memory, the dedicated processor may be configured to execute instructions stored on the memory to receive commands from the processor(s) associated with video, audio, other sensory data, control data, location data, etc., including capture commands, processing commands, motion commands, and/or transmission commands. The transceiver may include a wired or wireless communication device capable of transmitting data to or from one or more other components in system **40**. In some embodiments, the transceiver can receive data from the processor(s), including instructions for sensor and/or actuator activation and for the transmission of data via the transceiver. In response to the received instructions, the transceiver can packetize and transmit data between the processor(s) and the other components.

(57) FIG. **3** is a flowchart depicting an example method that may be implemented by controller **44** during preparation, planning, application, and/or quality control processes performed by machine **12**. FIG. **3** will be discussed in detail in the following section to further illustrate the disclosed concepts.

INDUSTRIAL APPLICABILITY

(58) The disclosed machines, system and methods may improve the building and performance of roads. For example, the roads may be built safer, faster, cheaper, and better using the disclosed machines, system and methods. Operation of the disclosed machine(s), control system and method(s) will be described in detail below, with reference to FIGS. **1-3**. It should be noted that the methods (e.g., the method of FIG. **3**) may be implemented in whole or in part by controller **44**. Alternatively, the methods may be implemented in whole or in part by a separate device that is configured to communicate with controller **44** and/or another processor located onboard or offboard machines **12**. Accordingly, while the steps described below will be referenced as performed by controller **44**, this reference is intended to describe any one or more of the above-mentioned processors.

(59) As shown in the example method **300** of FIG. **3**, at a start of a road building process, various information may be collected and/or received by controller **44**. For example, information may be collected about surface **18** on which road **14** is to be built (Step **302**), information may be collected about environment **10** surrounding surface **18** and/or about a history of surface **18** and/or a previous road at the intended location of new road **14** (Step **304**), and information may be received about road **14** that is to be built (Step **306**).

(60) In the disclosed embodiment, the information collected at Step **302** may include, among other things, a texture of surface **18**. For the purposes of this disclosure, the texture of surface **18** may be defined as a measured deviation in height of surface **18** (e.g., from a theoretical or ideal contour or plane, from an average texture across the width of surface **18**, etc.). The contour, if non-planar, may be defined by an engineer responsible for designing road **14**. In some embodiments, the contour may have a crown shape.

(61) The texture of surface **18** may be collected via any one or more of the example input devices described above and/or other devices known in the art. The texture may be collected via these devices during travel of the distributor (or another machine **12**) along surface **18** before the application of any material, during the application of material (e.g., in real or near-real time), and/or after the application of material. Additionally or alternatively, the texture may be downloaded from one or more local and/or remote databases **46**. Likewise, any texture data that is newly collected may be uploaded to the same or different databases **46**.

(62) For example, during a travel pass along a finite length of surface **18**, surface input device(s) **52** may scan a transverse swath (e.g., a point, multiple points, a line, and/or an area) of surface **18** at a location in front of, below, and/or behind machine **12**, and generate one or more texture signals indicative of the texture of surface **18** across the swath. These signals may be indexed according to a transverse location within the array at which each device **52** is performing the scanning (e.g., within the first foot, second foot, third foot, etc., across the sixteen-foot width of machine **12**), as well as a location along a length of surface **18**. In some embodiments, coordinates (e.g., one, two, or three-dimensional coordinates) generated by device **48** at the same time that texture scanning is occurring may be stored together with each signal generated by each corresponding device **52**. It is contemplated that the texture signals may additionally be indexed according to date and/or time, if desired. Controller **44** may receive these signals, analyze the signals, process the signals, store the signals and/or processing, and/or build a virtual texture map associated with the area being scanned.

(63) An example texture map **42** generated by controller **44** is illustrated in FIG. **2** (e.g., on surface **18**, between the front wheels of vehicle **20**). As shown in FIG. **2**, values representative of the texture of surface **18**, as generated by input devices **52** and/or analyzed/processed by controller **44**, may be placed into map **42** based on the corresponding coordinates discussed above. In the example map **42**, sixteen data points have been entered into each row of map **42**. Each data point may represent an area having a width of about one foot, and a dimension in the length of surface **18** of a predetermined amount (e.g., an amount equal to a spray diameter of nozzle **30**). Additional rows of map **42** may be populated as machine **12** advances along the length of surface **18**. Each column of map **42** may correspond with a particular input device **52** and also particular spray area of an individual nozzle **30** or of a grouping of nozzles **30** that are independently controlled.

(64) In one embodiment, the data points entered into each cell of the virtual map described above and shown in FIG. **2** are actual textural measurements, as produced by input devices **52**. In another embodiment, the data points are represented as deviations from a nominal value. The nominal value may be, for example, a value set by a user of system **40** (e.g., a value associated with the theoretical plane or contour discussed above). Alternatively, the nominal value may be a value calculated as an average of texture measurements taken for each cell, each row, for multiple rows, for a finite length and/or area of surface **18**, for an entire length and/or area of surface **18**, or for another data range specified by the user. Other strategies may also be employed.

(65) The environmental information collected at Step **304** may include, for example, geographical information, climate information, weather information, and/or traffic information. The geographical information may include, among other things, information about geographical features under, on, and/or adjacent surface **18** that could affect the building and/or performance of road **14**. This may include, for example, an orientation and/or distance of surface **18** relative to the sun or a known wind-flow pattern (e.g., direct exposure, indirect exposure, no exposure); the location of a feature (e.g., a cliff, tree, water body, etc.) **57** that might block sun exposure, increase humidity, or function as a heat sink; a grade of surface **18** relative to a known traffic flow (e.g., uphill or downhill, with or against travel) or area of interest (e.g., a mall, a school, etc.); an altitude; etc. Climate information may include historical temperatures (e.g., highs, lows, averages, swings, durations, etc.); humidity levels; precipitation amounts and forms; wind speeds, durations, and/or patterns; traffic patterns, volumes and/or densities; etc. Weather information may include conditions (e.g., any of the above-mentioned parameters) anticipated and/or actually experienced at a time of road building (e.g., historical road building and/or current road building). The information may be collected via any one or more of the example input devices described above and/or other devices known in the art. The information may be collected via these devices during travel of the distributor (or another machine **12**) along surface **18** before the application of any material and/or during the application of material (e.g., in real or near-real time during material discharge from distribution arrangement **24**). Additionally or alternatively, the geographical, climate, weather, and/or other GIS information may be pulled from one or more local and/or remote databases **46**.
(66) For example, during a travel pass along a finite length of surface **18**, input device **50** may capture images of an area in front of, behind, above, below, and/or to the sides of machine **12** and generate one or more signals indicative of the geography of surface **18** and/or the environment **10** surrounding surface **18**. These signals may be indexed according to a location at which device **50** is performing the image capture (e.g., based on signals from device **48**) and/or according to date and/or time. At the same or a different date and/or time, one or more additional devices may generate one or more signals indicative of the temperature, humidity, light intensity, wind speed, wind direction, etc. associated with the weather at the time of material application and/or under conditions that should be similar to the conditions expected at the time of road building. Additionally or alternatively, historical information regarding the climate of environment **10** may be downloaded from local and/or remote databases **46**. These signals and/or information may be directed to and/or pulled by controller **44** for processing.
(67) The road history data collected at Step **304** may include, among other things, parameters (e.g., material formulas, mixtures, layer numbers, layer thicknesses, aggregate specifications, temperatures, distribution rates, corresponding coordinates, weather conditions during past building events, contractor identification, etc.) historically used to build previous roads and corresponding historical performance of the previous roads at the same location of the new road **14**. The historical performance may include, among other things, information about repairs that have been made, maintenance activities that occurred, how often the road was plowed or sealed, reports of vehicular damage caused by road degradation, and/or observed failures (e.g., unraveling)—along with corresponding coordinates, dates and/or times.
(68) The road information collected at Step **306** may include, for example, specifications for surface **18**, road **14**, and/or the materials (e.g., material formula, temperature and/or viscosity; aggregate size, shape, amount; etc.); machines **12** and/or processing parameters to be used in building road **14**; etc. Although this information may typically be collected from an engineer responsible for the design of road **14** and/or applicable regulatory agencies (e.g., downloaded from local and/or remote databases **46** housing such information), it is contemplated that this information may additionally or alternatively be generated during road building, if desired. For example, while a type and/or size of aggregate may be specified for use in building road **14**, it is contemplated that the type and/or size of aggregate actually being used may be different and

detectible during application (e.g., in real or near-real time) via one or more of the input devices (e.g., sensor **58**) described above.

(69) It should be noted that Steps **302-306** may be performed simultaneously, or sequentially in any order. Further, Steps **304** and/or **306** may be performed after Step(s) **308** and/or **310** (yet to be described), if desired.

(70) In some embodiments, after completion of at least Step **302**, controller **44** may be configured to divide surface **18** into one or more virtual segments (see areas of common shading within map **42** of FIG. **2**). In some embodiments, the dividing may be performed based on an area scannable by each device **52** (e.g., based on an average texture value measured within each scannable area). In other embodiments, the dividing may be performed based on a minimum area of resolution possible with nozzle(s) **30**. In other embodiments, the scannable area and the minimum area of resolution may both be considered.

(71) The overall range of textures measured and/or range of deviations from averaged or normalized values entered into map **42** may be divided into any number of subranges. The number of subranges may be based on a number of discrete application rates possible and/or desirable via arrangement **24**. In the example of FIG. **2**, the overall range of detectable values is 0.0 to 5.0 mm, and the number of subranges is selected to be three. The three different subranges in the example of FIG. **2** include a first subrange (0.0 to 1.0 mm), a second subrange (1.0 to 3.0 mm), and a third subrange (3.0 to 5.0 mm). Each cell within map **42** may then be designated generally as falling into subrange I, subrange II, or subrange III and represented within map **42** (e.g., by a different shading).

(72) Controller **44** may then be configured to determine and/or assign an application rate of material (e.g., emulsion, slurry, asphalt, cement, primer, hardener, etc.) to each of the three subranges. The determination may be made based on the texture values (e.g., deviations from an average value) of the ranges, the environmental data, the road history data, the desired roadway parameters, the material details, etc. collected and/or received at Steps **304-306**.

(73) In one example, controller **44** may first determine a base application rate (the “base rate”) for each subgroup dependent primarily on a texture value, an average value, or a deviation from a threshold value for the corresponding subrange and the road parameters received at Step **306** (Step **310**). This determination may be made based on any method known in the art (e.g., the McLeod Chip Seal Design Method, the Hanson Method, the Modified Kearby Method, etc.). For instance, the portions of surface **18** that have been segmented into subgroup I may be assigned a base rate of 0.1 gal/yd based on an average texture of 0.5 mm; the portions of surface **18** that have been segmented into subgroup II may be assigned a base rate of 0.12 gal/yd based on an average texture of 2.0 mm; and the portions of surface **18** that have been segmented into subgroup III may be assigned a base rate of 0.14 gal/yd based on an average texture of 4.0 mm.

(74) The base application rates may then be selectively adjusted higher or lower according to the other data collected and/or received at Step **304** (Step **312**). For example, the base application rates may be selectively increased or decreased according to the environmental information and/or historical information.

(75) For example, when a particular subgroup of surface segments is generally shaded by a geographical feature (e.g., a berm, a cliff, a mountain, a tree, a building, etc.) **23**, the base rate for that subgroup may be selectively increased (e.g., by 0-5%, 5-10%, 10-20%, or 0-20%). In another instance, known proximal features that are likely to increase traffic flow (e.g., the location of a school or a shopping mall) may be cause for controller **44** to increase (e.g., by 0-5%, 5-10%, 10-20%, or 0-20%) the base rates of corresponding subgroups in the vicinity of the features. Similar regulation may be selectively implemented in areas that experience greater amounts of snow (e.g., geographical areas of higher elevation), due to mechanical forces of a plow acting on the aggregate within the corresponding subgroups. Areas likely to experience greater torsional forces on the aggregate (e.g., tight corners, sudden inclines, etc.) may also receive increased rates (e.g., by 0-5%,

5-10%, 10-20%, or 0-20%). In other areas located close to humidity sources (e.g., near bodies of water) and/or heat sinks (e.g., ravines), controller **44** may again increase the base rates (e.g., by 0-5%, 5-10%, 10-20%, or 0-20%). These increased base rates may provider greater adhesion in areas where the subsequently applied aggregate might otherwise tend to unravel.
(76) While the above-cited examples focus adjustment according to historical and/or long-term conditions, controller **44** may similarly adjust the base rates according to actual and/or anticipated short-term information. For example, the base rates may be selectively increased or decreased based on anticipated and/or actual weather conditions (e.g., sun intensity, precipitation, temperature, etc.) and/or actual (e.g., measured) material conditions (e.g., temperature, viscosity, asphalt parameters, aggregate parameters, etc.) experienced during the road building event. For instance, controller **44** may selectively decrease (e.g., by 0-5%, 5-10%, 10-20%, or 0-20%) the base application rate when the temperature during building of road **14** is higher than the anticipated or historical temperatures.
(77) The historical information may likewise be used by controller **44** to selectively increase or decrease the base rates. For example, controller **44** may consider parameters (e.g., application rates, aggregate specifications, etc.) used to build a section of an earlier or existing road at the same location intended for new road **14**, along with a performance history (reports of bleeding, slippery roads, unraveling, vehicular damage, road failure, repairs, etc.) of the old road. For instance, based on a report of asphalt bleeding up through the aggregate and/or slippery roads, controller **44** may selectively decrease (e.g., by 0-5%, 5-10%, 10-20%, or 0-20%) the base application rate from what was used before. Similarly, based a report of unraveling and/or vehicular damage, controller **44** may selectively increase (e.g., by 0-5%, 5-10%, 10-20%, or 0-20%) the base application rate.
(78) It should be noted that the general conditions described above as resulting in selective increases in the base application rate are examples only. In some situations, these same conditions could result in controller **44** selectively decreasing the base application rates, if desired. It should also be noted that, while mostly selective increases in the base application rates have been discussed above, selective decreases may be similarly implemented in response to the conditions following a generally opposite trend.
(79) It is contemplated that, in addition to or instead of adjusting the base rates in the manners described above, controller **44** may selectively adjust properties of the materials being applied at the base rates. For example, controller **44** may selectively adjust a formulation of the materials (e.g., by mixing an additive into vessel **22** and/or implementing use of the primer), a temperature of the materials (e.g., by activating a heater **23** in vessel **22**), a viscosity of the materials (e.g., by implementing use of the hardener), etc.
(80) Controller **44** may generate the plan (e.g., texture map **42**, road segmentation, the base rates for each segment, and selective adjustments to the base rates) for building road **14**, and also regulate operation of machine(s) **12** to effectuate the plan (Step **314**). In some embodiments, the plan is generated completely before building of road **14** begins. In these embodiments, the plan may be adjusted in real or near-real time during the building process as new information is received and processed by controller **44**. In other embodiments, controller **44** may generate the plan during the building process (e.g., during the application of material to surface **18**). In either situation, the plan may be executed in a semi-autonomous or completely autonomous manner (Step **314**).
(81) In semi-autonomous operations, the operator may maneuver an appropriately supplied/configured distributor (and/or other road building machines **12**) to a start of surface **18** that is to be built up. In some applications, the operator may then signal a start to the road building operation (e.g., by activating arrangement **24** via control devices **38**), and begin driving the distributor down the length of surface **18**. In other applications, controller **44** may detect arrival at the start location and automatically activate arrangement **24**.
(82) In autonomous operations, controller **44** may regulate both the driving of the distributor and activation of arrangement **24** at the same time.

(83) In either situation, as the distributor travels along surface **18**, controller **44** may selectively activate and/or adjust the various components of arrangement **24** based on the plan. For example, controller **44** may selectively energize/de-energize/adjust pump(s) **26**, spray bar(s) **28**, nozzle(s) **30**, valves **32**, actuators **34**, and/or conditioning devices. **23** associated with vessels **22** to achieve the adjusted base rates (and/or other parameters, such as temperature, viscosity, formula, etc.) of material application specified in the plan for each segment of surface **18**.
(84) Controller **44** may monitor the various input devices described above to ensure that, regardless of variations in driving control of the distributor, the plan is still executed. For example, controller may monitor the location, orientation, heading, ground speed, etc. of the distributor, determine an amount of delay between when a particular segment of surface **18** is first scanned for texture by a particular input device **52** and when that same segment passes into the spray area of a particular nozzle **30**, and actively regulate the flow of material from that nozzle **30** to cover the segment with the planned amount of material. Similarly, controller **44** may monitor that same segment as it is covered with aggregate by the spreader to ensure that the aggregate specified for that segment is the same aggregate spread onto the segment and in the specified amount.
(85) Controller **44** may adjust operation of arrangement **24** and/or machine **12** in a feed-forward, feed-back, and/or combination strategy. For example, based on the adjusted base rate for each segment of surface **18** and a monitored velocity of machine **12**, controller **44** may determine a required flowrate of material through each nozzle **30** and adjust various settings of arrangement **24** based one or more known relationships stored in memory. Alternatively, the settings of arrangement **24** may be set to nominal values, and the flowrates of material through individual nozzles **30** and/or the buildup of material on individual segments may be monitored to generate feedback data (Step **316**). Controller **44** may then incrementally adjust operation of arrangement **24** until the actual or monitored flowrates and/or buildup matches desired values. Finally, controller **44** may specify the original settings of arrangement **24** based on stored relationships, monitor results of these settings, and thereafter responsively adjust the settings as necessary. The monitoring of flowrates and/or buildup may be performed by any one or more of the input devices described above.
(86) The feedback data generated at Step **316** from the various input devices associated with machine(s) **12** during the road building process may be used in a number of different ways, beyond regulation of the machines **12** during the process. For example, the feedback data may be stored together with the plan in one or more databases (e.g., database **46**—referring to FIG. **2**) for future use in rebuilding road **14** (e.g., to adjust future base rates based on actual performance). Additionally or alternatively, the feedback data may be used to confirm adherence to the plan, road specifications, and/or regulatory requirements. The feedback data may also be used for invoicing purposes (for example to quantify an amount, quality, and/or type of material used).
(87) In some applications, the feedback generated at Step **316** may be used to schedule other operations associated with the road building process. For example, based on a monitored rate of material application (e.g., as observed via a thickness buildup, as imaged via a spray pattern, as detected via a flow rate, as indicated via a sonar level sensor and/or weight sensor associated with vessel **22**, etc.), controller **44** may be capable of forecasting when and/or at what locations along surface **18** machine **12** requires refilling. Controller **44** may then be configured to automatically communicate (e.g., via a communication device—not shown) with a supply contractor, a machine operator, and/or a refilling machine itself (e.g., an autonomous machine) and coordinate a rendezvous at the anticipated refill location. In this manner, delays associated with refilling may be reduced.
(88) The disclosed machine, system and method may improve the process of building and the quality of road **14**. The process may be improved by reducing a time, labor and material cost associated with road **14**. The time and labor may be reduced by automating many steps in the process via unique algorithms, and simultaneously implementing multiple operations in real or

near-real time. The quality of road **14** may be improved by ensuring a "right" amount of the right material is applied to at all areas of road **14**, taking into account geographical considerations, climate considerations, weather considerations, and history.

(89) It will be apparent to those skilled in the art that various modifications and variations can be made to the disclosed machine, system and methods. Other embodiments will be apparent to those skilled in the art from consideration of the specification and practice of the disclosed machine, system and methods. For example, in some embodiments, it may be possible to omit texture detection and instead determine the application rates for the different segments of surface **18** in another manner. It may still be possible to track location information for each of these segments and regulate operation of arrangement **24** in the same manner discussed above. In another example, although much of this disclosure focuses on regulating application rates of sprayed materials from a distributor, the disclosed methods could similarly be applied to the application of aggregate by a spreader based on detected textures and/or machine location. It is intended that the specification and examples be considered as exemplary only, with a true scope being indicated by the following claims and their equivalents.

Claims

1. A method of building a road, comprising: moving a machine over a surface on which the road is to be built; generating a signal indicative of a texture of the surface during movement of the machine over the surface; detecting a location of the texture on the surface; determining, using a specially programmed processor, an amount of a material to be applied to the location of the texture on the surface based on the signal; and automatically applying the amount of the material to the location of the texture on the surface to build the road, wherein: the material is an asphalt material; the amount of the material is selected at least in part based on a specified parameter of an aggregate to be subsequently applied on top of the material; and the method further includes: detecting an actual parameter of the aggregate during application of the aggregate on to the material; and selectively adjusting the amount of the material being applied based on the actual parameter of the aggregate.