

MOTION CONTROL METHOD AND SYSTEM FOR TROWELING ROBOT AND TROWELING ROBOT

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims priority to Chinese Patent Application No. 202210216646.8,
5 filed with the China National Intellectual Property Administration on March 7, 2022, and entitled
"MOTION CONTROL METHOD AND SYSTEM FOR TROWELING ROBOT AND
TROWELING ROBOT", which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

The present application relates to the field of robot control technologies, and in particular, to a
10 motion control method and system for a troweling robot, a troweling robot, an electronic device,
and a computer-readable storage medium.

BACKGROUND

A troweling robot functions to perform press polish on a concrete surface after initial setting
of concrete and before final setting. The concrete surface troweled by the robot is smoother and
15 flatter than that having undergone manual construction, compactness and wear resistance of the
concrete surface can be greatly improved, and the robot improves operation efficiency by 5 times
or above than manual operation. Ground troweling robots can be widely used for mud extracting,
screeding and troweling of concrete surfaces of high-standard factories, warehouses, parking lots,
squares, airports, and frame buildings.

20 In related technologies, troweling robots on the market are generally grouped into hand-held
semi-automatic apparatuses and riding semi-automatic apparatuses. Both the hand-held and the
riding troweling robots perform wipe pressure and press polish on the ground by using
propeller-type trowels with rotating power. When the troweling robot performs ground construction,
the ground environment is constantly changing. A control system of the troweling robot is a
25 nonlinear time-varying system, it is difficult to precisely and automatically control a position, an
attitude, a velocity, etc. of the troweling robot, and the troweling robot has a poor anti-interference
capability and poor robustness. Currently, the hand-held troweling robots rely on a manual
operation handle to guide the movement of the apparatus, and the riding troweling robots rely on a

manual operating lever to guide the movement of the apparatus. The hand-held troweling robots and the riding troweling robots cannot get rid of the limitation of manual operation, and construction efficiency is low.

SUMMARY

5 An objective of embodiments of the present application is to provide a motion control method and system for a troweling robot, a troweling robot, an electronic device, and a computer-readable storage medium, so as to achieve at least a technical effect of improving precision and smoothness of motion control of the troweling robot.

10 Some embodiments of the present application provide a motion control method for a troweling robot, which may include:

obtaining kinetics parameter information and motor load rate information of the troweling robot;

obtaining environmental information of a position of the troweling robot;

15 inputting the motor load rate information and the environmental information into a preset neural network to obtain ground environment parameter information;

inputting the kinetics parameter information and the ground environment parameter information into a model predictive controller to obtain inclination adjustment information; and

controlling a troweling plate mechanism of the troweling robot based on the inclination adjustment information.

20 In the foregoing implementation process, in the motion control method for a troweling robot, model-based predictive control is implemented by using the model predictive controller. In the motion control method, based on the model predictive controller of the troweling robot, a robot body state (the motor load rate information and the kinetics parameter information) and the ground environment parameter information of the troweling robot are used as feedback inputs, so as to
25 predict and comprehensively optimize a state and an inclination output of the troweling robot, and then calculate current optimal inclination adjustment information, so that precise and smooth motion control of the troweling robot can be implemented in different ground environments. Therefore, the motion control method for a troweling robot can achieve a technical effect of improving precision and smoothness of motion control of the troweling robot.

Optionally, the troweling robot may include a positioner, an inertial measurement unit, and a vision sensor, and the step of obtaining kinetics parameter information and motor load rate information of the troweling robot may include:

obtaining the motor load rate information of the troweling robot;

5 obtaining positioner data, inertial measurement unit data, and vision sensor data; and

performing sensor fusion on the positioner data, the inertial measurement unit data, and the vision sensor data to obtain the kinetics parameter information, where the kinetics parameter information includes position information, velocity information, attitude angle information, and angular velocity information.

10 In the foregoing implementation process, the positioner, the inertial measurement unit and the vision sensor are installed on the troweling robot to sense states such as a position, an attitude, a velocity, and ground information of a robot body, thereby providing a highly robust multi-sensor fusion-motion state sensing solution.

Optionally, the environmental information may include ground humidity information, and the
15 step of inputting the motor load rate information and the environmental information into a preset neural network to obtain ground environment parameter information may include:

obtaining motor load change rate information based on the motor load rate information; and

inputting the motor load rate information, the motor load change rate information and the ground humidity information into the preset neural network to obtain the ground environment
20 parameter information.

In the foregoing implementation process, the motor load change rate information may be obtained by calculating the motor load rate information. Based on the preset neural network, a large number of ground environment labels (ground humidity information) and motor load rate information are collected, and input into the preset neural network for training to obtain a nonlinear
25 relationship between a ground environment friction coefficient, a motor load rate, and humidity, so as to obtain corresponding ground environment parameter information and implement precise sensing of the ground environment friction coefficient.

Optionally, the step of inputting the kinetics parameter information and the ground environment parameter information into a model predictive controller to obtain inclination

adjustment information may include:

obtaining kinetics parameter setting data;

inputting the kinetics parameter setting data, the kinetics parameter information and the ground environment parameter information into the model predictive controller, and modifying and
5 generating a linearized kinetics prediction model;

generating an objective function of the model predictive controller based on the linearized kinetics prediction model; and

solving the objective function and obtaining the inclination adjustment information.

In the foregoing implementation process, the kinetics parameter setting data, the kinetics
10 parameter information and the ground environment parameter information are input into the model predictive controller. The ground environment parameter information is used as a modification parameter to finally generate the objective function of the model predictive controller. This objective function is based on a preset kinetics model and the ground environment parameter information, and takes a machine state and output at a current moment and a period of time in the
15 future as optimized cores, and a maximum adjustment quantity of an inclination of the troweling plate mechanism and a response time may be taken into account, thereby implementing precise construction and intelligent construction of the troweling robot and improving operation efficiency of the troweling robot.

Optionally, in the step of inputting the kinetics parameter setting data, the kinetics parameter
20 information and the ground environment parameter information into the model predictive controller, and modifying and generating a linearized kinetics prediction model, the linearized kinetics prediction model includes a linearized kinetics formula, and the linearized kinetics formula is:

$$\dot{X} = AX + BU,$$

where X is a difference matrix between the kinetics parameter setting data and the kinetics
25 parameter information, U is inclination information of the troweling plate mechanism, A is a first coefficient matrix, B is a second coefficient matrix, and the first coefficient matrix and the second coefficient matrix are determined by a mechanical structure of the troweling robot and the ground environment parameter information.

Optionally, in the step of generating an objective function of the model predictive controller

based on the linearized kinetics prediction model, the objective function is:

$$J = 0.5 \cdot \Delta \bar{U}^T H \Delta \bar{U} + p^T \Delta \bar{U},$$

where $\Delta \bar{U}$ is a one-dimensional matrix composed of output variations of the troweling robot from a current moment to a future control domain moment, H is a third coefficient matrix, and p is a fourth coefficient matrix.

Optionally, the step of controlling a troweling plate mechanism of the troweling robot based on the inclination adjustment information may include:

obtaining current position parameter information of the troweling robot; and

controlling the troweling plate mechanism of the troweling robot based on the current position parameter information and the inclination adjustment information.

Some other embodiments of the present application provide a motion control system for a troweling robot, which may include:

a first obtaining module, which may be configured to obtain kinetics parameter information and motor load rate information of the troweling robot;

a second obtaining module, which may be configured to obtain environmental information of a position of the troweling robot;

a ground environment parameter module, which may be configured to input the motor load rate information and the environmental information into a preset neural network to obtain ground environment parameter information;

an inclination adjustment information module, which may be configured to input the kinetics parameter information and the ground environment parameter information into a model predictive controller to obtain inclination adjustment information; and

a control module, which may be configured to control a troweling plate mechanism of the troweling robot based on the inclination adjustment information.

Optionally, the troweling robot may include a positioner, an inertial measurement unit, and a vision sensor, and the first obtaining module may include:

a first obtaining unit, which may be configured to obtain the motor load rate information of the troweling robot;

a second obtaining unit, which may be configured to obtain positioner data, inertial

measurement unit data, and vision sensor data; and

a fusion unit, which may be configured to perform sensor fusion on the positioner data, the inertial measurement unit data, and the vision sensor data to obtain the kinetics parameter information, where the kinetics parameter information includes position information, velocity
5 information, attitude angle information, and angular velocity information.

Optionally, the environmental information may include ground humidity information, and the ground environment parameter module may include:

a motor load change rate unit, configured to obtain motor load change rate information based on the motor load rate information; and

10 a ground environment parameter unit, configured to input the motor load rate information, the motor load change rate information and the ground humidity information into the preset neural network to obtain the ground environment parameter information.

Optionally, the inclination adjustment information module may include:

a setting data obtaining unit, which may be configured to obtain kinetics parameter setting
15 data;

a linearized kinetics unit, which may be configured to input the kinetics parameter setting data, the kinetics parameter information and the ground environment parameter information into the model predictive controller, and modify and generate a linearized kinetics prediction model;

an objective function unit, which may be configured to generate an objective function of the
20 model predictive controller based on the linearized kinetics prediction model; and

an inclination adjustment information unit, which may be configured to solve the objective function and obtain the inclination adjustment information.

Optionally, the control module may include:

a current position parameter unit, which may be configured to obtain current position
25 parameter information of the troweling robot; and

a control unit, which may be configured to control the troweling plate mechanism of the troweling robot based on the current position parameter information and the inclination adjustment information.

Some other embodiments of the present application provide a troweling robot, where motion

of the troweling robot performs the motion control method for a troweling robot according to the foregoing embodiments.

Some other embodiment of the present application provide an electronic device, including a memory, a processor, and a computer program stored in the memory and capable of running on the processor, where when the processor executes the computer program, the steps of the method according to the foregoing embodiments can be implemented.

Another embodiment of the present application provides a computer-readable storage medium, where instructions are stored on the computer-readable storage medium, and when the instructions are run on a computer, the computer is enabled to perform the method according to the foregoing embodiments.

Other embodiments of the present application provide a computer program product, where when the computer program product runs on a computer, the computer is enabled to perform the method according to the foregoing embodiments.

Other features and advantages disclosed in the present application are set forth in the subsequent specification, or some features and advantages may be inferred from the specification or determined undoubtedly, or may be learned by implementing the foregoing techniques disclosed in the present application.

To make the foregoing objectives, features and advantages of the present application more obvious and understandable, preferred embodiments will be described in detail below with reference to accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

To more clearly illustrate the technical solutions of the embodiments of the present application, the accompanying drawings required in the description of the embodiments of the present application will be described briefly below. It should be understood that the following accompanying drawings show only some embodiments of the present application, and therefore should not be regarded as limiting the scope. For a person of ordinary skill in the art, other relevant accompanying drawings can also be obtained according to these accompanying drawings without creative efforts.

FIG. 1 is a schematic flowchart of a motion control method for a troweling robot according to

an embodiment of the present application;

FIG. 2 is a schematic flowchart of another motion control method for a troweling robot according to an embodiment of the present application;

FIG. 3 is a schematic structural diagram of a troweling robot according to an embodiment of
5 the present application;

FIG. 4 is a schematic structural diagram of a troweling robot according to an embodiment of the present application at another perspective;

FIG. 5 is a structural block diagram of a motion control system for a troweling robot according to an embodiment of the present application; and

10 FIG. 6 is a structural block diagram of an electronic device according to an embodiment of the present application.

Reference numerals: 101 - positioner; 102 - first troweling plate mechanism; 103 - second troweling plate mechanism; 104 - troweling plate inclination control mechanism; 105 - vision sensor; 106 - troweling plate inclination shaft; 107 - inclination shaft adjustment motor; 110 - first
15 obtaining module; 120 - second obtaining module; 200 - ground environment parameter module; 300 - inclination adjustment information module; 400 - control module; 510 - processor; 520 - communication interface; 530 - memory; and 540 - communication bus.

DESCRIPTION OF EMBODIMENTS

Technical solutions in embodiments of the present application are described below with
20 reference to the accompanying drawings in the embodiments of the present application.

It should be noted that similar reference numerals and letters indicate similar items in the following accompanying drawings. Therefore, once an item is defined in one accompanying drawing, the item does not need to be further defined and explained in subsequent accompanying drawings. In addition, in the description of the present application, the terms such as "first" and
25 "second" are used for distinguishing in description only, and cannot be construed as indicating or implying relative importance.

Embodiments of the present application provide a motion control method and system for a troweling robot, an electronic device, and a computer-readable storage medium, which can be applied to a troweling operation process of a troweling robot. In the motion control method for a

troweling robot, model-based predictive control is implemented by using a model predictive controller. In the motion control method, based on the model predictive controller of the troweling robot, a robot body state (motor load rate information and kinetics parameter information) and ground environment parameter information of the troweling robot are used as feedback inputs, so as to predict and comprehensively optimize a state and an inclination output of the troweling robot, and then calculate current optimal inclination adjustment information, so that precise and smooth motion control of the troweling robot can be implemented in different ground environments. Therefore, the motion control method for a troweling robot can achieve a technical effect of improving precision and smoothness of motion control of the troweling robot.

FIG. 1 is a schematic flowchart of a motion control method for a troweling robot according to an embodiment of the present application. The motion control method for a troweling robot includes the following steps.

S110: Obtain kinetics parameter information and motor load rate information of the troweling robot.

S120: Obtain environmental information of a position of the troweling robot.

For example, the motor load rate information, i.e., a motor load rate of a spindle of the troweling robot, may reflect ground friction to a certain extent; and the environmental information includes ground humidity information, which may be obtained by a vision sensor mounted on the troweling robot.

For example, the kinetics parameter information includes information of the troweling robot, such as a position, an attitude, a velocity, and an angular velocity.

S200: Input the motor load rate information and the environmental information into a preset neural network to obtain ground environment parameter information.

For example, the ground environment parameter information includes a ground environment friction coefficient. The motor load rate information and the ground humidity information are input into the preset neural network, so that the preset neural network is trained by using a large amount of data, the ground environment friction coefficient is precisely estimated based on the current motor load (the motor load rate information) and humidity (the ground humidity information), and estimated information is provided to the model predictive controller to modify a kinetics model.

For example, the operation of the model predictive controller includes inputting kinetics parameters and ground information, obtaining and modifying the kinetics model, and then solving inclination adjustment information based on the objective function in a preset control domain and a control domain, that is, in this embodiment of the present application, the model predictive controller is used to solve the optimal inclination.

S300: Input the kinetics parameter information and the ground environment parameter information into a model predictive controller to obtain inclination adjustment information.

S400: Control a troweling plate mechanism of the troweling robot based on the inclination adjustment information.

For example, based on kinetics modeling, the model predictive controller can determine changes in the ground environment (a friction coefficient) with the help of the neural network, predict a state quantity and an output quantity of the troweling robot in a period of time in future, and establish a comprehensive objective optimization function. Therefore, the inclination adjustment information is an optimal control quantity, and the inclination shaft of the troweling plate mechanism is adjusted by using the information, so that the troweling robot can always maintain desired kinetics parameters. When disturbed by the outside world, the troweling robot can restore stability in a short time. This method differs from a conventional method in that not only the current state of the robot is taken into account, but also a future state is predicted and regarded as one of optimization indexes, and thus the method has good foresight and implements a great degree of intelligence.

In some implementations, in the motion control method, based on the model predictive controller of the troweling robot, a robot body state (the motor load rate information and the kinetics parameter information) and the ground environment parameter information of the troweling robot are used as feedback inputs, so as to predict and comprehensively optimize a state and an inclination output of the troweling robot, and then calculate current optimal inclination adjustment information, so that precise and smooth motion control of the troweling robot can be implemented in different ground environments. Therefore, the motion control method for a troweling robot can achieve a technical effect of improving precision and smoothness of motion control of the troweling robot, improve operation efficiency of the robot, and reduce a construction

failure rate of the robot.

FIG. 2 is a schematic flowchart of another motion control method for a troweling robot according to an embodiment of the present application.

For example, the troweling robot includes a positioner, an inertial measurement unit, and a vision sensor, and step S110 of obtaining kinetics parameter information and motor load rate information of the troweling robot includes the following steps.

S111: Obtain the motor load rate information of the troweling robot;

S112: Obtain positioner data, inertial measurement unit data, and vision sensor data.

S113: Perform sensor fusion on the positioner data, the inertial measurement unit data, and the vision sensor data to obtain the kinetics parameter information, where the kinetics parameter information includes position information, velocity information, attitude angle information, and angular velocity information.

For example, the positioner, the inertial measurement unit (IMU) and the vision sensor are installed on the troweling robot to sense states such as a position, an attitude, a velocity, and ground information of a robot body, thereby providing a highly robust multi-sensor fusion-motion state sensing solution. Optionally, the positioner may be a global navigation satellite system (GNSS) positioner, a base station navigation positioner, or the like. A specific positioning manner of the positioner is not limited herein.

For example, obtaining the motion state information of the current troweling robot is the basis for implementing motion control of the current troweling robot. The GNSS, the IMU and the vision sensor can sense information such as a position, an attitude, a velocity, and an angular velocity of the robot body. The advantages of the three sensors are complementary to each other, and the information fusion of the three sensors can provide state information with centimeter-level precision for the troweling robot. There is often no GPS signal on a construction site, but the fusion of the IMU and the vision sensor can still improve positioning with relatively high precision. In addition, the vision sensor can also identify an obstacle and a ground environment.

For example, the environmental information includes ground humidity information, and step S200 of inputting the motor load rate information and the environmental information into a preset neural network to obtain ground environment parameter information includes the following steps.

S210: Obtain motor load change rate information based on the motor load rate information.

S220: Input the motor load rate information, the motor load change rate information and the ground humidity information into the preset neural network to obtain the ground environment parameter information.

5 For example, the motor load change rate information may be obtained by calculating the motor load rate information. Based on the preset neural network, a large number of ground environment labels (ground humidity information) and motor load rate information are collected, and input into the preset neural network for training to obtain a nonlinear relationship between a ground environment friction coefficient, a motor load rate, and humidity, so as to obtain
10 corresponding ground environment parameter information and implement precise sensing of the ground environment friction coefficient.

In some implementation scenarios, differences in humidity and a poured material on a construction working surface of the troweling robot may affect friction stress on a trowel, thereby having an important impact on the motion control of the troweling robot. The vision sensor can
15 determine the ground humidity, while the motor load rate of the spindle of the troweling robot may reflect the ground friction to a certain extent. The neural network trained by using a large amount of data accurately estimates the ground environment friction coefficient based on the current motor load and the humidity, and provides the estimated information to the model predictive controller to modify the preset kinetics model.

20 For example, step S300 of inputting the kinetics parameter information and the ground environment parameter information into a model predictive controller to obtain inclination adjustment information includes the following steps.

S310: Obtain kinetics parameter setting data.

S320: Input the kinetics parameter setting data, the kinetics parameter information and the
25 ground environment parameter information into the model predictive controller, and modify and generate a linearized kinetics prediction model.

S330: Generate an objective function of the model predictive controller based on the linearized kinetics prediction model.

S340: Solve the objective function and obtain the inclination adjustment information.

For example, the controller is a motion control mechanism of the troweling robot. The kinetics parameter setting data is set desired data, such as a desired position, a desired velocity, and a desired attitude angle of the troweling robot. The kinetics parameter setting data, the kinetics parameter information and the ground environment parameter information are input into the model predictive controller. The ground environment parameter information is used as a modification parameter to finally generate the objective function of the model predictive controller. This objective function is based on a preset kinetics model and the ground environment parameter information, and takes a machine state and output at a current moment and a period of time in the future as optimized cores, and a maximum adjustment quantity of an inclination of the troweling plate mechanism and a response time may be taken into account, thereby implementing precise construction and intelligent construction of the troweling robot and improving operation efficiency of the troweling robot.

For example, in the step of inputting the kinetics parameter setting data, the kinetics parameter information and the ground environment parameter information into the model predictive controller, and modifying and generating a linearized kinetics prediction model, the linearized kinetics prediction model includes a linearized kinetics formula, and the linearized kinetics formula is:

$$\dot{X} = AX + BU,$$

where X is a difference matrix between the kinetics parameter setting data and the kinetics parameter information, U is inclination information of the troweling plate mechanism, A is a first coefficient matrix, B is a second coefficient matrix, and the first coefficient matrix and the second coefficient matrix are determined by a mechanical structure of the troweling robot and the ground environment parameter information.

For example, in the step of generating an objective function of the model predictive controller based on the linearized kinetics prediction model, the objective function is:

$$J = 0.5 \cdot \Delta \bar{U}^T H \Delta \bar{U} + p^T \Delta \bar{U},$$

where $\Delta \bar{U}$ is a one-dimensional matrix composed of output variations of the troweling robot from a current moment to a future control domain moment, H is a third coefficient matrix, and p is a fourth coefficient matrix.

For example, the third coefficient matrix and the fourth coefficient matrix are related

parameters determined by a predicted state quantity, a predicted output quantity, a control domain, a predicted domain, a control coefficient weight, etc.

For example, step S400 of controlling a troweling plate mechanism of the troweling robot based on the inclination adjustment information includes:

5 S410: Obtain current position parameter information of the troweling robot.

 S420: Control the troweling plate mechanism of the troweling robot based on the current position parameter information and the inclination adjustment information.

For example, the troweling robot can be adjusted to a desired state (i.e., a target state) by combining the current position parameter information and the inclination adjustment information.

10 FIG. 3 is a schematic structural diagram of a troweling robot according to an embodiment of the present application, and FIG. 4 is a schematic structural diagram of a troweling robot according to an embodiment of the present application at another perspective. The troweling robot includes a robot body, a positioner 101, a first troweling plate mechanism 102, a second troweling plate mechanism 103, a troweling plate inclination control mechanism 104, a vision sensor 105, a
15 troweling plate inclination shaft 106, and an inclination shaft adjustment motor 107.

For example, the objective of the motion control method for a troweling robot according to this embodiment of the present application is to provide a motion control method for a troweling robot based on model predictive control, which solves the problem that currently, a troweling robot relies on manual auxiliary traction and cannot move independently and precisely.

20 For example, to enable the troweling robot to sense a motion state of the robot body and the ground environment, a highly robust multi-sensor fusion solution is provided. The positioner 101, the IMU and the vision sensor 105 (binocular camera) installed on the troweling robot can sense information of the robot body such as the position, the attitude, the velocity, and the angular velocity. The positioner 101 can implement long-term positioning, but has a low data update
25 frequency, leading to a risk of signal loss. The IMU has a high data update frequency, and has high data precision in a short time. In a long time, a GPS can calibrate an IMU error to ensure precision. In a short time, the IMU can provide positioning data with a higher frequency, and reduce the risk of signal loss of the positioner 101 to some extent. The data frequency and positioning precision of the vision sensor 105 depend on the quality of the sensor and a corresponding vision algorithm.

The addition of the vision sensor improves robustness of an entire positioning system. Even if the signal of the positioner 101 is completely lost, the dual fusion of the IMU and the vision sensor 105 can still ensure certain precision. In addition, the vision sensor 105 can determine obstacle information around the robot body, and can also determine humidity of a ground environment based on a photographed photo. The advantages of the three sensors are complementary to each other, and the information fusion of the three sensors can provide state information with centimeter-level precision for the troweling robot.

For example, to enable the troweling robot to sense the ground environment more precisely, so as to modify ground friction information in the kinetics model and help the controller to adapt to ground changes, a method for online prediction of ground environment parameter information based on a preset neural network is provided. The vision sensor 105 can determine the humidity of the ground environment, and a motor load of the spindle of the troweling robot can reflect a magnitude of friction of the ground environment. The neural network trained by using a large amount of ground humidity and motor load data can describe this nonlinear relationship, so that the trained neural network can sense ground environment changes in real time.

For example, to enable the troweling robot to intelligently adjust a troweling plate to control the troweling robot to reach a desired state, a motion control method for a troweling robot based on model predictive control is provided. The method is based on information of the model predictive controller, takes a machine state and output at a current moment and a period of time in the future as optimized cores, and can also take into account a maximum adjustment quantity of an inclination of the troweling plate and a response time. Different from a conventional method, this method has certain predictability. Through continuous rolling optimization and feedback correction, an optimal output quantity of the inclination of the troweling plate at a current moment and a period of time in the future can be obtained, and the controller selects the output quantity at the current moment as a current inclination adjustment quantity.

With reference to FIG. 1 to FIG. 4, an example of a specific application process of the motion control method for a troweling robot according to this embodiment of the present application is provided below.

Step 1: Obtain, by a vision sensor 105, a ground humidity coefficient (ground humidity

information) based on a photographed ground image, read a motor load (motor load rate information) of the troweling robot from a motor driver, and place the troweling robot on a friction experimental platform (this platform is a self-designed platform, and the design idea is to lay, at a bottom layer on the platform with a fixed base, a same concrete material as that at a construction site, allow the machine to move at different velocities and angular velocities on the platform under different humidity conditions, and deduce a friction force on the robot body by using a tension sensor, a torque sensor, motion data of the machine, etc.), so that friction reaction forces on the troweling robot under different humidity conditions and loads can be obtained. Train the neural network through collection and labeling of a large number of data (the neural network is a fully connected neural network, and the number of layers and the number of neurons at each layer are determined by the data volume and computing power).

Step 2: Obtain kinetics parameter setting data, including desired positions x_d and y_d , a traveling velocity V_d , and a desired attitude angle ϕ_d .

Step 3: Perform sensor fusion (the fusion is based on an extended Kalman filter) on data of the positioner 101, the IMU, and the vision sensor 105, to obtain information of the robot body of the troweling robot, such as an actual position $[x, y]$, a velocity v , an attitude angle ϕ , and an angular velocity ω . The first troweling plate mechanism 102 and the second troweling plate mechanism 103 are jointly controlled by a spindle motor in the troweling robot, and are kept synchronous, and a process of interaction between the two mechanisms and the ground affects the load of the spindle motor. The rotating speeds of the troweling plate mechanisms may be set by a remote controller or a machine APP.

Step 4: Read motor load rate information L from the spindle motor driver, and calculate motor load change rate information $\dot{L}$. Obtain ground humidity information λ from the vision sensor.

Step 5: Input $[L, \dot{L}, \lambda]$ into the preset neural network to obtain a friction correction coefficient γ .

Step 6: Transfer ground environment change information to a kinetics equation $f(x, u)$ for correction, and take local linearization measures for the kinetics equation, and finally obtain a linearized kinetics equation as follows: $\dot{X} = AX + BU$.

$X = [x - x_d, y - y_d, \phi - \phi_d, v - v_d]^T$, and $U = [\theta_L, \theta_R]^T$ indicates inclinations of the first

troweling plate mechanism 102 and the second troweling plate mechanism 103. The first coefficient matrix and the second coefficient matrix are determined by a specific mechanical structure of the troweling robot and the ground information.

Step 7: Use a kinetics equation obtained in step 6 as a prediction model, where an objective function of the model predictive controller has the following specific form: $J = 0.5 \cdot \Delta \bar{U}^T H \Delta \bar{U} + p^T \Delta \bar{U}$; matrices H and p are determined by a predicted state quantity, a predicted output quantity, a control domain, a predicted domain, a control coefficient weight, etc., and $\Delta \bar{U}$ is a one-dimensional matrix composed of output variation quantities from a current moment to a future control domain moment; perform, by the model predictive controller, quadratic programming solution on the objective function under specified constraint conditions (such as a maximum adjustment value of the inclination and adjustment of a response speed), and find out optimal inclination values θ_L and θ_R that the current troweling plates (the first troweling plate mechanism 102 and the second troweling plate mechanism 103) need to reach.

Step 8: Adjust the position φ of a troweling plate inclination shaft 106 by an inclination shaft adjustment motor 107, so that a troweling plate inclination control mechanism 104 (this mechanism is fixedly connected to the inclination shaft, with the equal inclination) reaches given inclinations θ_L and θ_R , where the troweling robot is provided with the troweling plate inclination shaft adjustment motor.

There is a quantitative and accurate mathematical relationship between φ and θ_L and θ_R . As shown in FIG. 4, based on the mathematical relationship, after θ_L and θ_R are obtained, φ is obtained by reverse deduction. A motor position mode may quickly adjust the inclination shaft motor to the position φ without using another adjustment algorithm. This can quickly and quantitatively adjust the inclination and improve the response. The mathematical relationship is as follows:

$$\theta = \arcsin\left(\frac{W(\varphi)}{2\sqrt{a(\varphi)^2 + b(\varphi)^2}}\right) - \arcsin\left(\frac{b(\varphi)}{2\sqrt{a(\varphi)^2 + b(\varphi)^2}}\right),$$

where the specific expressions of W , a and b are related to the design size of the robot body structure.

Step 9: After the adjustment of the troweling plate inclination is completed, perform step 2 again for the next cycle (a single cycle of the controller takes 10 ms) until the construction target is completed.

FIG. 5 is a structural block diagram of a motion control system for a troweling robot according to an embodiment of the present application. The motion control system for a troweling

robot includes:

a first obtaining module 110, configured to obtain kinetics parameter information and motor load rate information of the troweling robot;

5 a second obtaining module 120, configured to obtain environmental information of a position of the troweling robot;

a ground environment parameter module 200, configured to input the motor load rate information and the environmental information into a preset neural network to obtain ground environment parameter information;

10 an inclination adjustment information module 300, configured to input the kinetics parameter information and the ground environment parameter information into a model predictive controller to obtain inclination adjustment information; and

a control module 400, configured to control a troweling plate mechanism of the troweling robot based on the inclination adjustment information.

15 For example, the troweling robot includes a positioner, an inertial measurement unit, and a vision sensor, and the first obtaining module 110 includes:

a first obtaining unit, configured to obtain the motor load rate information of the troweling robot;

a second obtaining unit, configured to obtain positioner data, inertial measurement unit data, and vision sensor data; and

20 a fusion unit, configured to perform sensor fusion on the positioner data, the inertial measurement unit data, and the vision sensor data to obtain the kinetics parameter information, where the kinetics parameter information includes position information, velocity information, attitude angle information, and angular velocity information.

25 For example, the environmental information includes ground humidity information, and the ground environment parameter module 200 includes:

a motor load change rate unit, configured to obtain motor load change rate information based on the motor load rate information; and

a ground environment parameter unit, configured to input the motor load rate information, the motor load change rate information and the ground humidity information into the preset neural

network to obtain the ground environment parameter information.

For example, the inclination adjustment information module 300 includes:

a setting data obtaining unit, configured to obtain kinetics parameter setting data;

a linearized kinetics unit, configured to input the kinetics parameter setting data, the kinetics
 5 parameter information and the ground environment parameter information into the model
 predictive controller, and modify and generate a linearized kinetics prediction model;

an objective function unit, configured to generate an objective function of the model
 predictive controller based on the linearized kinetics prediction model; and

an inclination adjustment information unit, configured to obtain the inclination adjustment
 10 information based on the objective function.

Optionally, the control module includes:

a current position parameter unit, configured to obtain current position parameter information
 of the troweling robot; and

a control unit, configured to control the troweling plate mechanism of the troweling robot
 15 based on the current position parameter information and the inclination adjustment information.

It should be understood that the motion control system for a troweling robot shown in FIG. 5
 corresponds to the method embodiments shown in FIG. 1 to FIG. 4. To avoid repetition, details are
 not described herein again.

The present application further provides an electronic device. FIG. 6 is a structural block
 20 diagram of an electronic device according to an embodiment of the present application. The
 electronic device may include a processor 510, a communication interface 520, a memory 530, and
 at least one communication bus 540. The communication bus 540 is configured to implement direct
 connection communication between these components. The communication interface 520 of the
 electronic device in this embodiment of the present application is used for signaling or data
 25 communication with another node device. The processor 510 may be an integrated circuit chip with
 a signal processing capability.

The foregoing processor 510 may be a general-purpose processor, including a central
 processing unit (CPU), a network processor (NP), etc.; or may be a digital signal processor (DSP),
 an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or

another programmable logic device, a discrete gate or a transistor logic device, and a discrete hardware component. The methods, steps, and logic block diagrams disclosed in the embodiments of the present application can be implemented or performed. The general-purpose processor may be a microprocessor or the processor 510 may be any conventional processor or the like.

5 The memory 530 may be, but is not limited to, a random access memory (RAM), a read only memory (ROM), a programmable read-only memory (PROM), an erasable programmable read-only memory (EPROM), an electric erasable programmable read-only memory (EEPROM), etc. Computer-readable instructions are stored in the memory 530, and when the computer-readable instructions are executed by the processor 510, the electronic device may perform the steps
10 involved in the foregoing method embodiments of FIG. 1 to FIG. 4.

Optionally, the electronic device may further include a storage controller and an input/output unit.

The memory 530, the storage controller, the processor 510, a peripheral interface, and the input/output unit are electrically connected to each other directly or indirectly to implement data
15 transmission or interaction. For example, these elements may be electrically connected to each other through one or more communication buses 540. The processor 510 is configured to execute an executable module stored in the memory 530, such as a software functional module or a computer program included in the electronic device.

The input/output unit is configured to provide a user with a task to be created and create an
20 optional start-up period of time or preset an execution time for the task, to implement interaction between the user and a server. The input/output unit may be, but is not limited to, a mouse, a keyboard, etc.

It can be understood that the structure shown in FIG. 6 is only schematic, and the electronic device may also include more or fewer components than those shown in FIG. 6, or have a different
25 configuration from that shown in FIG. 6. The components shown in FIG. 6 may be implemented by using hardware, software or a combination thereof.

An embodiment of the present application further provides a storage medium, where instructions are stored on the storage medium, and when the instructions are run on a computer and a computer program is executed by a processor, the method according to the method embodiment is

implemented. To avoid repetition, details are not described herein again.

The present application further provides a computer program product, where when the computer program product runs on a computer, the computer is enabled to perform the method according to the method embodiment.

5 In several embodiments of the present application, it should be understood that the disclosed apparatus and method may be implemented in another manner. The foregoing apparatus embodiments are only schematic. For example, the flowcharts and block diagrams in the accompanying drawings show architectures, functions and operations of possible implementations of the apparatuses, methods, and computer program products according to various embodiments of
10 the present application. In this regard, each block in the flowchart or block diagram may represent a module, a program segment or part of code, and the module, the program segment or the part of code includes one or more executable instructions for implementing a specified logic function. It should also be noted that in some alternative implementations, functions marked in the blocks may be performed in an order different from those marked in the accompanying drawings. For example,
15 two consecutive blocks can actually be executed substantially in parallel, or may sometimes be executed in a reverse order, depending on the functions involved. It should also be noted that each block in the block diagram and/or the flowchart, and the combination of blocks in the block diagram and/or the flowchart, may be implemented by using a dedicated hardware-based system that performs specified functions or actions, or may be implemented by using a combination of
20 dedicated hardware and computer instructions.

In addition, the functional modules in each embodiment of the present application may be integrated together to form an independent part, or each module may exist alone, or two or more modules may be integrated to form an independent part.

If the functions are implemented in the form of software function modules and sold or used as
25 independent products, they may be stored in a computer-readable storage medium. Based on such understanding, the technical solutions of the present application essentially, or the part that contributes to a related technology, or part of the technical solutions may be embodied in the form of a software product, and the computer software product is stored in one storage medium, and includes several instructions to enable a computer device (which may be a personal computer, a

server, a network device, or the like) to perform all or some steps of the method according to each of the embodiments of the present application. The foregoing storage medium includes various media that can store program code, such as a USB flash drive, a mobile hard disk, a read only memory (ROM), a random access memory (RAM), a magnetic disk, or a compact disc.

5 The above are only embodiments of the present application, and are not intended to limit the protection scope of the present application. Various modifications and variations may be made to the present application for a person skilled in the art. Any modification, equivalent replacement, improvement, etc. made within the spirit and principles of the present application should fall within the protection scope of the present application. It should be noted that similar reference numerals
10 and letters indicate similar items in the following accompanying drawings. Therefore, once an item is defined in one accompanying drawing, the item does not need to be further defined and explained in subsequent accompanying drawings.

 The foregoing descriptions are merely specific implementations of the present application, but the protection scope of the present application is not limited thereto. Any person skilled in the art
15 can easily conceive modifications or replacements within the technical scope disclosed in the present application, and these modifications or replacements shall fall within the protection scope of the present application. Therefore, the protection scope of the present application shall be subject to the protection scope of the claims.

 It should be noted that herein, relational terms such as “first” and “second” are used only to
20 distinguish one entity or operation from another, and do not necessarily require or imply that any such actual relationship or sequence exists between these entities or operations. In addition, the term "including", "comprising" or any other variant thereof is intended to cover non-exclusive inclusion, so that a process, method, article or device including a series of elements includes not only those elements, but also other elements not explicitly listed, or elements inherent to such a
25 process, method, article or device. Without further limitation, an element defined by the sentence “including a...” does not exclude that other identical elements are also present in the process, method, article or device including the element.

Industrial practicability

Embodiments of the present application provide a motion control method and system for a

troweling robot and a troweling robot. The motion control method for a troweling robot includes: obtaining kinetics parameter information and motor load rate information of the troweling robot; obtaining environmental information of a position of the troweling robot; inputting the motor load rate information and the environmental information into a preset neural network to obtain ground
5 environment parameter information; inputting the kinetics parameter information and the ground environment parameter information into a model predictive controller to obtain inclination adjustment information; and controlling a troweling plate mechanism of the troweling robot based on the inclination adjustment information. The motion control method for a troweling robot can achieve a technical effect of improving precision and smoothness of motion control of the
10 troweling robot.

In addition, it can be understood that the motion control method and system for a troweling robot and a troweling robot according to the present application can be reproduced, and can be used in various industrial applications. For example, the motion control method and system for a troweling robot and a troweling robot according to the present application can be used in the field
15 of robot control technologies.

CLAIMS

1. A motion control method for a troweling robot, comprising:

obtaining kinetics parameter information and motor load rate information of the troweling robot;

5 obtaining environmental information of a position of the troweling robot;

inputting the motor load rate information and the environmental information into a preset neural network to obtain ground environment parameter information;

inputting the kinetics parameter information and the ground environment parameter information into a model predictive controller to obtain inclination adjustment information; and

10 controlling a troweling plate mechanism of the troweling robot based on the inclination adjustment information.

2. The motion control method for a troweling robot according to claim 1, wherein the troweling robot comprises a positioner, an inertial measurement unit, and a vision sensor, and the step of obtaining kinetics parameter information and motor load rate information of the troweling robot comprises:

obtaining the motor load rate information of the troweling robot;

obtaining positioner data, inertial measurement unit data, and vision sensor data; and

performing sensor fusion on the positioner data, the inertial measurement unit data, and the vision sensor data to obtain the kinetics parameter information, wherein the kinetics parameter information comprises position information, velocity information, attitude angle information, and angular velocity information.

3. The motion control method for a troweling robot according to claim 2, wherein the environmental information comprises ground humidity information, and the step of inputting the motor load rate information and the environmental information into a preset neural network to obtain ground environment parameter information comprises:

obtaining motor load change rate information based on the motor load rate information; and

inputting the motor load rate information, the motor load change rate information and the ground humidity information into the preset neural network to obtain the ground environment

parameter information.

4. The motion control method for a troweling robot according to any one of claims 1 to 3, wherein the step of inputting the kinetics parameter information and the ground environment parameter information into a model predictive controller to obtain inclination adjustment information comprises:

obtaining kinetics parameter setting data;

inputting the kinetics parameter setting data, the kinetics parameter information and the ground environment parameter information into the model predictive controller;

generating a linearized kinetics prediction model;

generating an objective function of the model predictive controller based on the linearized kinetics prediction model; and

solving the objective function and obtaining the inclination adjustment information.

5. The motion control method for a troweling robot according to claim 4, wherein in the step of inputting the kinetics parameter setting data, the kinetics parameter information and the ground environment parameter information into the model predictive controller, and generating a linearized kinetics prediction model, the linearized kinetics prediction model comprises a linearized kinetics formula, and the linearized kinetics formula is:

$$\dot{X} = AX + BU,$$

wherein X is a difference matrix between the kinetics parameter setting data and the kinetics parameter information, U is inclination information of the troweling plate mechanism, A is a first coefficient matrix, B is a second coefficient matrix, and the first coefficient matrix and the second coefficient matrix are determined by a mechanical structure of the troweling robot and the ground environment parameter information.

6. The motion control method for a troweling robot according to claim 4 or 5, wherein in the step of generating an objective function of the model predictive controller based on the linearized kinetics prediction model, the objective function is:

$$J = 0.5 \cdot \Delta \bar{U}^T H \Delta \bar{U} + p^T \Delta \bar{U},$$

wherein $\Delta \bar{U}$ is a one-dimensional matrix composed of output variations of the troweling

robot from a current moment to a future control domain moment, H is a third coefficient matrix, and p is a fourth coefficient matrix.

7. The motion control method for a troweling robot according to any one of claims 1 to 6, wherein the step of controlling a troweling plate mechanism of the troweling robot based on the inclination adjustment information comprises:

obtaining current position parameter information of the troweling robot; and

controlling the troweling plate mechanism of the troweling robot based on the current position parameter information and the inclination adjustment information.

8. A motion control system for a troweling robot, comprising:

a first obtaining module, configured to obtain kinetics parameter information and motor load rate information of the troweling robot;

a second obtaining module, configured to obtain environmental information of a position of the troweling robot;

a ground environment parameter module, configured to input the motor load rate information and the environmental information into a preset neural network to obtain ground environment parameter information;

an inclination adjustment information module, configured to input the kinetics parameter information and the ground environment parameter information into a model predictive controller to obtain inclination adjustment information; and

a control module, configured to control a troweling plate mechanism of the troweling robot based on the inclination adjustment information.

9. The motion control system for a troweling robot according to claim 8, wherein the troweling robot comprises a positioner, an inertial measurement unit, and a vision sensor, and the first obtaining module comprises:

a first obtaining unit, configured to obtain the motor load rate information of the troweling robot;

a second obtaining unit, configured to obtain positioner data, inertial measurement unit data, and vision sensor data; and

a fusion unit, configured to perform sensor fusion on the positioner data, the inertial measurement unit data, and the vision sensor data to obtain the kinetics parameter information,

wherein the kinetics parameter information comprises position information, velocity information, attitude angle information, and angular velocity information.

10. The motion control system for a troweling robot according to claim 8 or 9, wherein the environmental information comprises ground humidity information, and the ground environment
5 parameter module comprises:

a motor load change rate unit, configured to obtain motor load change rate information based on the motor load rate information; and

a ground environment parameter unit, configured to input the motor load rate information, the motor load change rate information and the ground humidity information into the preset neural
10 network to obtain the ground environment parameter information.

11. The motion control system for a troweling robot according to any one of claims 8 to 10, wherein the inclination adjustment information module comprises:

a setting data obtaining unit, configured to obtain kinetics parameter setting data;

a linearized kinetics unit, configured to input the kinetics parameter setting data, the kinetics
15 parameter information and the ground environment parameter information into the model predictive controller, and modify and generate a linearized kinetics prediction model;

an objective function unit, configured to generate an objective function of the model predictive controller based on the linearized kinetics prediction model; and

an inclination adjustment information unit, configured to obtain the inclination adjustment
20 information based on the objective function.

12. The motion control system for a troweling robot according to any one of claims 8 to 11, wherein the control module comprises:

a current position parameter unit, configured to obtain current position parameter information of the troweling robot; and

a control unit, configured to control the troweling plate mechanism of the troweling robot
25 based on the current position parameter information and the inclination adjustment information.

13. A troweling robot, wherein the troweling robot performs the motion control method for a troweling robot according to any one of claims 1 to 7.

14. An electronic device, comprising a memory, a processor, and a computer program stored
30 in the memory and running on the processor, wherein when the processor executes the computer

program, the steps of the motion control method for a troweling robot according to any one of claims 1 to 7 are implemented.