

MULTI-LEVEL EMERGENCY BRAKING CONTROL METHOD AND APPARATUS FOR RAIL TRANSIT TRAIN CONTROL SYSTEM, DEVICE AND MEDIUM

TECHNICAL FIELD

The present invention relates to train signal control systems, and in particular to a multi-level emergency brake control method and apparatus for a rail-transit train control system, a device, and a medium.

BACKGROUND

Currently, a hybrid braking system consisting of electric braking and pneumatic braking is employed in the majority of trains in rail transit, and the emergency braking is performed by pneumatic braking. Both electric braking and pneumatic braking achieve braking by applying a force onto the wheel tread to increase the force of friction between wheels and rails. During the design of the train control system, such force of friction (commonly referred to as a guaranteed emergency brake rate (GEBR)) is used to calculate and protect the safety distance.

For vehicles, the GEBR is calculated and verified on the basis of dry and straight rails. But in fact, under various specific weather or working conditions, for example, when oil stains or dew, etc. cause the rails to become slippery, the adhesion coefficient between wheels and rails deteriorates, thus resulting in the inability to guarantee the GEBR. This causes the train control system to fail to ensure train operation safety. Upon the occurrence of such a situation on the spot, it poses great threats to passenger safety. To address this problem, simply reducing the value of the GEBR will increase the safety protection distance of the train, thus resulting in excessively low line operation efficiency, which cannot meet the efficiency requirements of public transportation. On the other hand, adopting a higher braking system solution independent of the wheel-rail relation will cause sudden braking, which thus increases the risk of passenger's fall damage inside the train and accelerates wear on rails and wheels due to frequent braking.

CN112918508A discloses a magnetic rail braking system and a magnetic rail braking control method. The magnetic rail braking system includes a power supply, a control device, and an electromagnet assembly. The electromagnet assembly includes a core portion, a pole shoe portion below the core, and a coil assembly consisting of multiple sets of coils. Each coil in the coil

assembly is arranged along the length or width direction of the rail, and adjacent coils are insulated and isolated from each other. The coils in the coil assembly are divided into several independent groups, and the control device independently controls each group of coils. Moreover, the number of excitation coils is gradually increased or decreased to control the magnetic force of the electromagnet assembly step by step. The electromagnet assembly of the magnetic rail braking system is equipped with multiple sets of electromagnetic coils. Each group of coils is independently controlled, and the change of magnetic gradient of the electromagnet assembly is controlled by controlling the number of the excitation coils. In case of a local coil failure, other independent groups can still operate normally, allowing the entire magnetic rail braking system to operate in a degraded mode. This method achieves multi-level magnetic rail brake control by independently controlling each independent group of coils. However, the method neither takes the wheel-rail relation into account, nor does it consider how to ensure the safety of train brake control when a certain component fails.

SUMMARY

The objective of the present invention is to overcome the above deficiencies of the prior art and to provide a multi-level emergency brake control method and apparatus for a rail-transit train control system, a device, and a medium. Based on the real-time wheel-rail relation and the combination of multiple braking modes, a multi-level emergency brake control method is adopted for the train control system. Different braking modes are adopted according to different adhesion conditions, to ensure operational safety while maintaining efficiency.

The objective of the present invention may be achieved by the following technical solution:

According to a first aspect of the present invention, provided is a multi-level emergency brake control method for a rail-transit train control system, including the following steps:

obtaining train position and speed information;

determining whether to trigger an emergency brake command request according to the train position and speed information;

if the emergency brake command request is triggered, evaluating a wheel-rail relation based on the train position and speed information, and selecting a corresponding emergency brake mode and a corresponding emergency brake execution unit, wherein each emergency brake execution

unit corresponds to an emergency brake mode, and different emergency brake modes correspond to different braking rates; and

evaluating whether an emergency brake result meets an expectation; if the emergency brake result meets the expectation, executing a current emergency brake mode for braking using a corresponding emergency brake execution unit, and monitoring train position and speed conditions in real time during braking to update an emergency brake evaluation result; otherwise, reselecting the emergency brake mode and the emergency brake execution unit for braking.

As a preferred technical solution, the method for evaluating whether an emergency brake result meets an expectation includes: a final train stopping position is estimated during braking according to current train speed and braking rate; if the final train stopping position does not exceed a safety limit point, the emergency brake result meets the expectation, and the current emergency brake execution unit is continuously adopted for braking; if the final stopping position exceeds the safety limit point, the braking rate is increased, and an emergency brake execution unit having a larger braking rate is adopted for braking.

As a preferred technical solution, the emergency brake execution unit is configured in a heterogeneous manner, comprising one or more of shoe braking, disc braking, or magnetic rail braking.

As a preferred technical solution, the disc braking and the shoe braking have a braking rate range of $0.4-1.2 \text{ m/s}^2$, and a maximum braking rate of the magnetic rail braking is 2.0 m/s^2 .

According to a second aspect of the present invention, provided is a multi-level emergency brake control apparatus for a rail-transit train control system, including a speed detection positioning unit, a vehicle-mounted ATP protection unit, an emergency brake control unit, an emergency brake evaluation unit, and a plurality of emergency brake execution units; where,

the speed detection positioning unit provides train position and speed information for the vehicle-mounted ATP protection unit and the emergency brake evaluation unit;

the vehicle-mounted ATP protection unit outputs an emergency brake command request to the emergency brake control unit according to a protection principle of a train control system and based on the train position and speed information;

the emergency brake control evaluation unit evaluates a wheel-rail relation according to a braking strategy determined by the emergency brake control unit and the information provided

by the speed detection positioning unit, and evaluates whether a train braking condition meets an expectation;

the emergency brake control unit selects an emergency brake mode and a corresponding emergency brake execution unit to execute a brake command according to the emergency brake command request provided by the vehicle-mounted ATP protection unit and an evaluation result of the emergency brake control evaluation unit;

the emergency brake execution unit executes the brake command, where each emergency brake execution unit corresponds to an emergency brake mode, and different emergency brake modes correspond to different braking rates.

As a preferred technical solution, the method for evaluating whether an emergency brake result meets an expectation includes: estimating a final train stopping position during braking according to current train speed and braking rate; if the final train stopping position does not exceed a safety limit point, the emergency brake result meeting the expectation, and continuing to adopt the current emergency brake execution unit for braking; if the final stopping position exceeds the safety limit point, the braking rate being increased, and adopting an emergency brake execution unit having a larger braking rate for braking.

As a preferred technical solution, the emergency brake execution unit is configured in a heterogeneous manner, comprising one or more of shoe braking, disc braking, or magnetic rail braking.

As a preferred technical solution, the disc braking and the shoe braking have a braking rate range of $0.4\text{--}1.2\text{ m/s}^2$, and a maximum braking rate of the magnetic rail braking is 2.0 m/s^2 .

As a preferred technical solution, the emergency brake control unit issues a control command to each emergency brake execution unit via a separate interface.

As a preferred technical solution, an interface between the emergency brake control evaluation unit and the emergency brake control unit is a bidirectional interface for bidirectional information transmission, wherein the emergency brake control unit transmits the emergency brake command request to the emergency brake control evaluation unit via the interface, and the emergency brake control evaluation unit transmits the brake evaluation result to the emergency brake control unit via the interface.

As a preferred technical solution, the emergency brake control unit controls an emergency

brake relay by inverse logic, that is, a corresponding emergency brake relay does not activate emergency braking when energized and attracted, and initiates emergency braking only when the relay is de-energized and released.

As a preferred technical solution, when the emergency brake control evaluation unit fails to normally output the evaluation result, the emergency brake control unit outputs a default braking strategy, and selects a corresponding emergency brake mode and a corresponding emergency brake execution unit for emergency braking.

According to a third aspect of the present invention, provided is an electronic device, including a memory on which a computer program is stored, and a processor, when the processor executes the program, the method is implemented.

According to a fourth aspect of the present invention, provided is a computer-readable storage medium on which a computer program is stored; when the program is executed by a processor, the method is implemented.

Compared with the prior art, the present invention has the following beneficial effects:

1. According to the present invention, different emergency brake modes can be adopted according to the actual wheel-rail relation, different emergency brake execution units are selected for multi-level braking, thereby ensuring train braking stability while guaranteeing train operation safety.

2. Heterogeneous emergency brake execution units are adopted in the present invention, which can still ensure train operation safety even in the event of a single mode failure.

3. The present invention can still ensure that the system is guided to the safe side in the event of any single device fault, thereby guaranteeing train operation safety.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a flow chart of a method according to the present invention;

FIG. 2 is a structure chart of an apparatus according to the present invention; and

FIG. 3 is an example of a multi-level emergency brake control for a train control system in one embodiment.

DETAILED DESCRIPTION OF THE EMBODIMENTS

The technical solutions in the embodiments of the present invention will be described clearly and completely below with reference to the accompanying drawings in the embodiments of the present invention. Obviously, the described embodiments are merely a part of rather than all of the embodiments of the present invention. Based on the embodiments of the present invention, all other embodiments obtained by those skilled in the art without inventive efforts shall fall within the scope of protection of the present invention.

This embodiment first provides a multi-level emergency brake control method for a train control system in rail transit. As shown in FIG. 1, the method includes the following steps:

S1, obtaining train position and speed information;

S2, determining whether to trigger an emergency brake command request according to the train position and speed information;

S3, if the emergency brake command request is triggered, evaluating a wheel-rail relation based on the train position and speed information, and selecting a corresponding emergency brake mode and a corresponding emergency brake execution unit, wherein each emergency brake execution unit corresponds to an emergency brake mode, and different emergency brake modes correspond to different braking rates; and

S4, evaluating whether an emergency brake result meets an expectation; if the emergency brake result meets the expectation, executing a current emergency brake mode for braking using a corresponding emergency brake execution unit, and monitoring train position and speed conditions in real time during braking to update an emergency brake evaluation result; otherwise, reselecting the emergency brake mode and the emergency brake execution unit for braking.

The different emergency brake execution units mainly differ in the braking principles and brakes used, as well as in the indicators of the emergency braking rate. For example, the GEBR for disc braking and brake shoe braking ranges from 0.4 to 1.2 m/s², while magnetic rail braking may be up to 2.0 m/s² to the maximum. A higher braking rate means a shorter braking distance, but causes a greater impact on the train, track, and passengers during braking. In this embodiment, the emergency brake execution unit is configured in a heterogeneous manner, including one or more of shoe braking, disc braking, or magnetic rail braking.

In this embodiment, the method for evaluating whether an emergency brake result meets an expectation includes: estimating a final train stopping position during braking according to

current train speed and braking rate; if the final train stopping position does not exceed a safety limit point, the emergency brake result meeting the expectation, and continuing to adopt the current emergency brake execution unit for braking; if the final stopping position exceeds the safety limit point, the braking rate being increased, and adopting an emergency brake execution unit having a larger braking rate for braking.

The above introduces the method embodiments. The solutions in the present invention will be further described below via embodiments of the apparatus.

As shown in FIG. 2, the apparatus 300 includes: a speed detection positioning unit VDMU, a vehicle-mounted ATP protection unit ATPU, an emergency brake control unit EBC, an emergency brake evaluation unit EBA, and a plurality of emergency brake execution units EBE_i ($i = 1, \dots, n$); where,

The speed detection positioning unit VDMU provides train position and speed information for the vehicle-mounted ATP protection unit ATPU via an interface ①, and provides train position and speed information for the emergency brake evaluation unit via an interface ③.

The vehicle-mounted ATP protection unit ATPU outputs an emergency brake command request to the emergency brake control unit via an interface ② according to the protection principle of the train control system and based on the train position and speed information.

The emergency brake control evaluation unit EBA evaluates a wheel-rail relation according to a braking strategy determined by the emergency brake control unit and the information provided by the speed detection positioning unit, and evaluates whether a train braking condition meets an expectation.

The emergency brake control unit EBC selects an emergency brake mode and a corresponding emergency brake execution unit to execute a brake command according to the emergency brake command request provided by the vehicle-mounted ATP protection unit and an evaluation result of the emergency brake control evaluation unit.

The emergency brake execution unit executes the brake command, where each emergency brake execution unit corresponds to an emergency brake mode, and different emergency brake modes correspond to different braking rates.

The emergency brake control unit EBC may issue a command to the emergency brake execution unit EBE_1 via an interface ④, and the EBE_1 executes the brake command to stop the

train. Alternatively, a command may be also issued to the emergency brake execution unit EBE_i via an interface ⑤, and EBE_i executes the brake command to stop the train. EBE_i represents the i th emergency brake control execution unit configured by the system according to requirements. It needs to be noted that either EBC or each EBE_i adopts a separate interface, and issues a control command to each emergency brake execution unit via a separate interface. The interface ⑤ is merely one example.

The interface between the emergency brake control evaluation unit EBA and the emergency brake control unit EBC is a bidirectional interface for bidirectional information transmission. The emergency brake control unit EBC transmits the emergency brake command request to the emergency brake control evaluation unit via an interface ⑥. The emergency brake control evaluation unit EBA transmits the brake evaluation result to the emergency brake control unit EBC via the interface ⑥.

To ensure the availability of emergency braking in the system, different emergency brake execution units EBE are configured in a heterogeneous manner, including one or more of shoe braking, disc braking, or magnetic rail braking. In this embodiment, the disc braking and the shoe braking have a braking rate range of $0.4\text{--}1.2\text{ m/s}^2$, and the maximum braking rate of the magnetic rail braking is 2.0 m/s^2 .

The emergency brake control evaluation unit EBA determines possible train slip conditions based on the speed and positioning information from VDMU, and on this basis, issues an emergency brake mode command to the EBC according to the brake command. There are many causes of train slip, such as fallen leaves on the rails, oil applied during construction, light rain or snow, and creep control failure. Different wheel-rail relations may be obtained according to different slip conditions. If it is in normal mode, the emergency brake execution unit controlled by shoe braking or disc braking may be adopted; if it is in slip mode, the emergency brake unit controlled by magnetic rail braking needs to be adopted.

The method for evaluating whether train braking

meets an expectation by the emergency brake control unit EBA includes: a final train stopping position is estimated during braking according to current train speed and braking rate. If the final train stopping position does not exceed the safety limit point, it indicates that the emergency brake

result meets the expectation, and the current emergency brake execution unit continues to be used for braking. If the final train stopping position exceeds the safety limit point, the braking rate is increased, and EBA feeds back to EBC, then EBC issues a command to activate a higher-level scheme in other emergency brake modes, and an emergency brake execution unit having a greater braking rate is used for braking.

For example, when disc braking EBE_1 is adopted in the train according to the current brake strategy, the expected braking stop point of the train is located within the range of the safety limit point, and the train will continue to adopt this braking mode and monitor in real time whether it remains within the expected range. If it remains within the range, braking will ultimately be performed with this mode until the train stops. If the expected stop point of the train exceeds the range of the safety limit point, EBC may select shoe braking EBE_2 having a greater braking rate for braking, or may choose to activate the emergency brake execution unit EBE_3 for magnetic rail braking. The specific mode of selection depends on the number of the EBEs present, as well as the braking mode and braking rate corresponding to each EBE. If the braking rate corresponding to the EBE is graded more specifically, more precise the brake control may be achieved, which may improve braking smoothness while ensuring safety, to enhance user experience.

In this embodiment, the function of the emergency brake control unit to control the emergency brake relay is an SIL4 function, and inverse logic is adopted for control. That is, the relay is activated by the corresponding emergency brake execution unit, and emergency braking is not activated when the relay is energized and attracted; and only when the relay is de-energized and released, emergency braking is initiated.

To ensure that a single device failure does not cause a control failure of train operation safety, in this embodiment, when the emergency brake control evaluation unit fails to normally output the evaluation result, the emergency brake control unit outputs a default braking strategy, and selects a corresponding emergency brake mode and a corresponding emergency brake execution unit for emergency braking.

As shown in FIG. 3, if an emergency occurs during train operation, the train is required to not pass the protection point in the figure after emergency braking. At this time, EBA evaluates the wheel-rail relation based on the position and speed information provided by VDMU. If in

normal mode, EBC selects and activates the EBE corresponding to the way of shoe braking for emergency braking. If the wheel-rail relation is in slip mode, EBC selects and activates the EBE corresponding to the way of magnetic rail braking for emergency braking.

If, during shoe braking, the train EBA finds that braking efficiency may not meet the expectation, i.e., the requirement of not passing the protection point. For example, the estimated curve is S1, EBA feeds this information back to EBC at this time, and EBC selects and activates the EBE corresponding to the way of magnetic rail braking to ensure that the train braking curve does not exceed S2.

After train emergency braking, the safety protection boundary changes, and when the emergency braking condition no longer exists, EBC stops and outputs the emergency brake command.

In one scenario, when EBA fails and may not operate, EBC outputs magnetic rail braking by default and simultaneously issues an alarm.

The electronic device of the present invention includes a central processing unit (CPU). The CPU may execute various appropriate actions and processes according to the computer program instructions stored in a read-only memory (ROM) or the computer program instructions loaded from a storage unit into a random access memory (RAM). In the RAM, various programs and data required for the operation of the device may also be stored. The CPU, the ROM, and the RAM are connected to each other via a bus. An input/output (I/O) interface is also connected to the bus.

A plurality of components in the device are connected to the I/O interface, including: input units, such as a keyboard and a mouse; output units, such as various types of displays and loudspeakers; storage units, such as a disk and an optical disc; and communication units, such as a network card, a modem, and a wireless communication transceiver. The communication unit allows the device to exchange information/data with other devices through computer networks such as the Internet and/or various telecommunication networks.

The processing unit performs each of the methods and processes described above, such as methods S1 to S4. For example, in some embodiments, the methods S1 to S4 may be realized as a computer software program that is physically contained in a machine-readable medium, such as a storage unit. In some embodiments, part or all of the computer program may be loaded and/or

installed on the device via the ROM and/or the communication unit. When the computer program is loaded into the RAM and executed by the CPU, one or more steps of the methods S1 to S4 described above can be performed. Alternatively, in other embodiments, the CPU may be configured to execute the methods S1 to S4 by any other appropriate manner (e.g., by means of firmware).

The functions described above herein may be performed, at least in part, by one or more hardware logical components. For example, without limitation, available exemplary types of hardware logic components include: a field-programmable gate array (FPGA), an application-specific integrated circuit (ASIC), an application-specific standard product (ASSP), a system-on-chip (SOC), a complex programmable logic device (CPLD), and so on.

The program codes for implementing the method of the present invention may be written in any combination of one or more programming language. These program codes may be provided to a processor or controller of a general-purpose computer, a special-purpose computer or other programmable data processing device such that the program codes, when executed by the processor or controller, implements the functions/operations specified in the flow chart and/or block diagram. The program codes may be executed entirely on a machine, partially on a machine, partially on a machine and partially on a remote machine or completely on a remote machine or server as a stand-alone software package.

In the context of the present invention, the machine-readable medium may be a tangible medium that may contain or store a program for use by or in conjunction with an instruction executing system, apparatus or device. The machine-readable medium may be a machine-readable signal medium or a machine-readable storage medium. The machine-readable medium may include, but is not limited to, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, or device, or any suitable combination of the above. More specific examples of the machine-readable storage medium will include an electrical connection based on one or more wires, a portable computer disk, a hard disk, an RAM, an ROM, an erasable programmable ROM (EPROM or flash memory), an optical fiber, a convenient compact disk ROM (CD-ROM), an optical storage device, a magnetic storage device, or any suitable combination of the above.

The above are merely detailed embodiments of the present invention, but the protection

scope of the present invention is not limited thereto. Moreover, those skilled in the art could readily conceive of various equivalent amendments or replacements within the technical scope disclosed by the present invention; these amendments or replacements shall fall within the protection scope of the present invention. Therefore, the protection scope of the present invention shall be subject to the protection scope of the claims.

WHAT IS CLAIMED IS:

1. A multi-level emergency brake control method for a rail-transit train control system, comprising the following steps:

obtaining train position and speed information;

determining whether to trigger an emergency brake command request according to the train position and speed information;

if the emergency brake command request is triggered, evaluating a wheel-rail relation based on the train position and speed information, and selecting a corresponding emergency brake mode and a corresponding emergency brake execution unit, wherein each emergency brake execution unit corresponds to an emergency brake mode, and different emergency brake modes correspond to different braking rates; and

evaluating whether an emergency brake result meets an expectation; if the emergency brake result meets the expectation, executing a current emergency brake mode for braking using a corresponding emergency brake execution unit, and monitoring train position and speed conditions in real time during braking to update an emergency brake evaluation result; otherwise, reselecting the emergency brake mode and the emergency brake execution unit for braking.

2. The multi-level emergency brake control method for a rail-transit train control system according to claim 1, wherein a method for evaluating whether an emergency brake result meets an expectation comprises: estimating a final train stopping position during braking according to current train speed and braking rate; if the final train stopping position does not exceed a safety limit point, the emergency brake result meeting the expectation, and continuing to adopt the current emergency brake execution unit for braking; and if the final stopping position exceeds the safety limit point, increasing the braking rate, and adopting an emergency brake execution unit having a larger braking rate for braking.

3. The multi-level emergency brake control method for a rail-transit train control system according to claim 1, wherein the emergency brake execution unit is configured in a heterogeneous manner, comprising one or more of shoe braking, disc braking, or magnetic rail braking.

4. The multi-level emergency brake control method for a rail-transit train control system according to claim 3, wherein the disc braking and the shoe braking have a braking rate range of 0.4-1.2 m/s², and a maximum braking rate of the magnetic rail braking is 2.0 m/s².

5. A multi-level emergency brake control apparatus for a rail-transit train control system, comprising a speed detection positioning unit, a vehicle-mounted ATP protection unit, an emergency brake control unit, an emergency brake evaluation unit, and a plurality of emergency brake execution units; wherein,

the speed detection positioning unit provides train position and speed information for the vehicle-mounted ATP protection unit and the emergency brake evaluation unit;

the vehicle-mounted ATP protection unit outputs an emergency brake command request to the emergency brake control unit according to a protection principle of a train control system and based on the train position and speed information;

the emergency brake control evaluation unit evaluates a wheel-rail relation according to a braking strategy determined by the emergency brake control unit and the information provided by the speed detection positioning unit, and evaluates whether a train braking condition meets an expectation;

the emergency brake control unit selects an emergency brake mode and a corresponding emergency brake execution unit to execute a brake command according to the emergency brake command request provided by the vehicle-mounted ATP protection unit and an evaluation result of the emergency brake control evaluation unit; and

the emergency brake execution unit executes the brake command, wherein each emergency brake execution unit corresponds to an emergency brake mode, and different emergency brake modes correspond to different braking rates.

6. The multi-level emergency brake control apparatus for a rail-transit train control system according to claim 5, wherein a method for evaluating whether an emergency brake result meets an expectation comprises: estimating a final train stopping position during braking according to current train speed and braking rate; if the final train stopping position does not exceed a safety limit point, the emergency brake result meeting the expectation, and continuing to adopt the current emergency brake execution unit for braking; and if the final stopping position exceeds

the safety limit point, the braking rate being increased, and adopting an emergency brake execution unit having a larger braking rate for braking.

7. The multi-level emergency brake control apparatus for a rail-transit train control system according to claim 5, wherein the emergency brake execution unit is configured in a heterogeneous manner, comprising one or more of shoe braking, disc braking, or magnetic rail braking.

8. The multi-level emergency brake control apparatus for a rail-transit train control system according to claim 7, wherein the disc braking and the shoe braking have a braking rate range of $0.4-1.2 \text{ m/s}^2$, and a maximum braking rate of the magnetic rail braking is 2.0 m/s^2 .

9. The multi-level emergency brake control apparatus for a rail-transit train control system according to claim 5, wherein the emergency brake control unit issues a control command to each emergency brake execution unit via a separate interface.

10. The multi-level emergency brake control apparatus for a rail-transit train control system according to claim 5, wherein an interface between the emergency brake control evaluation unit and the emergency brake control unit is a bidirectional interface for bidirectional information transmission, wherein the emergency brake control unit transmits the emergency brake command request to the emergency brake control evaluation unit via the interface, and the emergency brake control evaluation unit transmits the brake evaluation result to the emergency brake control unit via the interface.

11. The multi-level emergency brake control apparatus for a rail-transit train control system according to claim 5, wherein the emergency brake control unit controls an emergency brake relay by inverse logic, that is, a corresponding emergency brake relay does not activate emergency braking when energized and attracted, and initiates emergency braking only when the relay is de-energized and released.

12. The multi-level emergency brake control apparatus for a rail-transit train control system according to claim 5, wherein when the emergency brake control evaluation unit fails to normally output the evaluation result, the emergency brake control unit outputs a default braking strategy, and selects a corresponding emergency brake mode and a corresponding emergency brake execution unit for emergency braking.

13. An electronic device, comprising a memory on which a computer program is stored, and a processor, wherein when the processor executes the program, the method according to any one of claims 1 to 4 is implemented.

14. A computer-readable storage medium on which a computer program is stored, wherein when the program is executed by a processor, the method according to any one of claims 1 to 4 is implemented.