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(71) Applicant: **Casco Signal Ltd.**
Shanghai 200435 (CN)

(72) Inventors:
- **WANG, Xiaoyong**
  Shanghai 200435 (CN)
- **XU, Ye**
  Shanghai 200435 (CN)
- **SUN, Yanqiong**
  Shanghai 200435 (CN)

(74) Representative: **Sun, Yiming**
HUASUN Patent- und Rechtsanwälte
Friedrichstraße 33
80801 München (DE)

(54) CBTC SYSTEM BASED ON INTERVAL PROTECTION AND HETEROGENEOUS REDUNDANCY, AND IMPLEMENTATION METHOD THEREFOR

(57) The present invention relates to a CBTC system based on interval protection and heterogeneous redundancy and an implementation method. the CBTC system includes a communication subsystem DCS and an onboard ATP subsystem MVTP and a trackside ATP interval protection subsystem MWSP that communicate with the communication subsystem DCS separately; the onboard ATP subsystem MVTP receives movement authority information from the trackside ATP interval protection subsystem MWSP, and receives, when the movement authority information is unavailable, information about a target distance or speed code to perform safe train running protection; and the trackside ATP interval protection subsystem MWSP automatically identifies and uses a corresponding block mode based on information sent by the onboard ATP subsystem MVTP, calculates movement authority and the target distance or speed code in the corresponding block mode, and sends a calculation result to a corresponding train. Compared with the prior art, the present invention has advantages that the system can still provide protection information for a train after the train is out of position, and maintains train running in ATP mode.

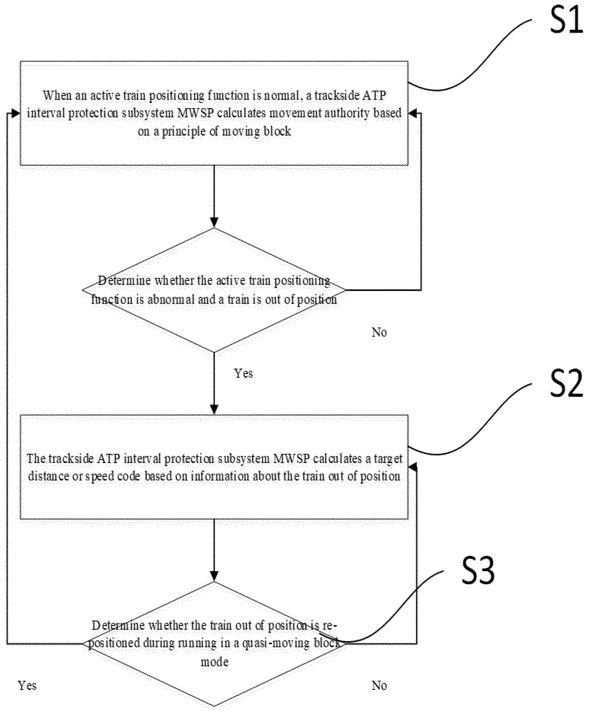

FIG. 4

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Description

TECHNICAL FIELD

[0001] The present invention relates to train interval protection of a CBTC system, and in particular to a CBTC system based on interval protection and heterogeneous redundancy and an implementation method.

BACKGROUND

[0002] Train interval protection is an important function to ensure safe train running. To ensure the safe train running, intervals should be kept between trains running on a same line, and the intervals usually depend on speeds, braking distances, safe protection distances, and other factors of the trains. In a specified section, a manner in which only one train is allowed to run is called block, which mainly includes fixed block, moving block, and quasi-moving block.

[0003] An existing CBTC system performs train interval protection based on active positioning and a principle of the moving block. The system causes a train to be out of position in the case of train skidding, instantaneous loss of a switch position, or the like. In this case, a trackside area controller cannot obtain position information of the train out of position, so that the train out of position cannot continue to run in ATP mode, which affects running of a subsequent train, resulting in a significant reduction in running efficiency of a whole line. At present, a multi-mode train control solution using BM+CBTC or TBTC+CBTC is used for resolving the problem.

[0004] However, in the two solutions, the other mode of train control system needs to be configured and integrated with an existing system, which increases the complexity of the system.

SUMMARY

[0005] The present invention provides a CBTC system based on interval protection and heterogeneous redundancy and an implementation method, to overcome defects in the prior art.

[0006] The purpose of the present invention is achieved using the following technical solutions:

According to a first aspect of the present invention, a CBTC system based on interval protection and heterogeneous redundancy is provided, and the CBTC system includes a communication subsystem DCS and an onboard ATP subsystem MVTP and a trackside ATP interval protection subsystem MWSP that communicate with the communication subsystem DCS separately;

the onboard ATP subsystem MVTP receives movement authority information from the trackside ATP interval protection subsystem MWSP, and receives, when the movement authority information is unavailable, information about a target distance or speed code to perform safe train running protection; and the trackside ATP interval protection subsystem MWSP automatically identifies and uses a corresponding block mode based on information sent by the onboard ATP subsystem MVTP, calculates movement authority and a target distance or speed code in the corresponding block mode, and sends a calculation result to a corresponding train.

[0007] In a preferred technical solution, the onboard ATP subsystem MVTP is compatible with modes of the movement authority and the speed code.

[0008] In a preferred technical solution, the trackside ATP interval protection subsystem MWSP performs self-adaptive operations of a moving block mode and a quasi-moving block mode based on an active train positioning state.

[0009] In a preferred technical solution, the movement authority is calculated for a train with a normal active positioning function and in ATP mode.

[0010] In a preferred technical solution, the target distance is calculated for a train with an abnormal active positioning function and in ATP mode.

[0011] In a preferred technical solution, the speed code is calculated for a train in an RM mode.

[0012] In a preferred technical solution, both the onboard ATP subsystem MVTP and the trackside ATP interval protection subsystem MWSP are a set of safety platforms.

[0013] According to a second aspect of the present invention, an implementation method for the CBTC system based on interval protection and heterogeneous redundancy is provided, specifically including the following steps:

step S1, when an active train positioning function is normal, calculating, by the trackside ATP interval protection subsystem MWSP, the movement authority based on a principle of moving block, and when the active train positioning function is abnormal and a train is out of position, performing step S2, otherwise performing step S1 again;

step S2, calculating, by the trackside ATP interval protection subsystem MWSP, the target distance or speed code based on information about a train out of position, and performing step S3; and

step S3, returning to step S1 if the train out of position is re-positioned during running in a quasi-moving block mode.

[0014] In a preferred technical solution, the movement authority in step S1 is received by the onboard ATP subsystem MVTP, and calculation of a safety protection

curve is calculated, to assist in train running.

[0015] In a preferred technical solution, the information about the train out of position in step S2 includes information about occupancy of a section in which a non-positioning envelope corresponding to the train out of position is located, information about permanent or temporary speed limit setting of a line, information about occupancy of adjacent trains or sections on the line, state information of trackside signaling equipment, and driving mode information of the train.

[0016] In a preferred technical solution, the trackside signaling equipment includes a signal, a switch, a platform emergency closing button, and a platform door.

[0017] In a preferred technical solution, the target distance in step S3 is calculated for a train in ATP mode.

[0018] In a preferred technical solution, the speed code in step S3 is calculated for a train in an RM mode.

[0019] In a preferred technical solution, the target distance or speed code in step S2 is received by the onboard ATP subsystem MVTP, and speed monitoring is performed on a running train out of position, to assist in train running.

[0020] According a third technical aspect of the present invention, an electronic device is provided, including a memory and a processor, where a computer program is stored in the memory, and when the processor executes the program, the above method is implemented.

[0021] According to a fourth aspect of the present invention, a computer-readable storage medium that stores a computer program is provided, and when the program is executed by a processor, the above method is implemented.

[0022] Compared with the conventional technologies, the present invention has the following advantages:

(1) In the present invention, the system can still provide ATP protection information for a train after the train is out of position based on trackside train occupancy detection, and maintain train running in ATP mode;

(2) In the present invention, through implementation of the heterogeneous redundancy of the interval protection function, a fusion operation of a plurality of interval protection modes such as the moving block and the quasi-moving block is implemented on a same set of safety platforms.

(3) In the present invention, self-adaption to a corresponding block mode is implemented based on different positioning modes for a train.

BRIEF DESCRIPTION OF DRAWINGS

[0023]

FIG. 1 is a schematic diagram of train running when an active train positioning function is normal according to the present invention;

FIG. 2 is a schematic diagram of train running when an active train positioning function is abnormal according to the present invention;

FIG. 3 is a schematic diagram of train running when a train is re-positioned during running in a quasi-moving block mode; and

FIG. 4 is a flow chart of an implementation method according to the present invention.

DESCRIPTION OF EMBODIMENTS

[0024] Technical solutions in embodiments of the present invention are clearly and completely described below with reference to accompanying drawings in the embodiments of the present invention. Apparently, the described embodiments are merely some rather than all of the embodiments of the present invention. Based on the embodiments of the present invention, all other embodiments obtained by those of ordinary skill in the art without creative effort shall fall within the protection scope of the present invention.

[0025] In the present invention, on the premise that only one set of CBTC systems is used, two different types of train positioning and detection systems including active train positioning and trackside train detection and positioning are fully used, heterogeneous redundancy is performed through moving block and fixed block separately, and corresponding movement authority or target distance information is provided for a train depending on whether a train is positioned or not. System availability is improved through software optimization without hardware configuration, and safety and efficiency of train running are ensured in case of a fault or being out of position.

[0026] As shown in FIG. 4. The present invention provides an implementation method for a CBTC method based on interval protection and heterogeneous redundancy, including the following steps:

step S1, when an active train positioning function is normal, trackside ATP interval protection equipment calculates train movement authority based on a principle of moving block and according to active train positioning information and sends the train movement authority to corresponding onboard equipment of a train, and the onboard equipment of the train calculates a safety protection curve based on the received movement authority and assists in train running;

step S2, when the onboard equipment of the train loses positioning for some reason, the trackside ATP interval protection equipment calculates a target distance (ATP mode) or speed code (RM mode)

based on information about occupancy of a section in which a non-positioning envelope corresponding to the train is located, permanent or temporary speed limit setting of a line, information about occupancy of adjacent trains or sections on the line, a state (a signal, a switch, a platform emergency closing button, a platform door, and the like) of trackside signaling equipment, and a driving mode of a train, and sends the speed code to the train out of position. The onboard equipment of the train out of position monitors a speed of the running train based on the received speed code and assists in train running; and

step S3, when the train out of position is re-positioned during running in a quasi-moving block mode, the train running goes back to a control mode of moving block, namely, step S1 in the flow.

[0027] The present invention is described below in detail with reference to drawings and specific embodiments.

[0028] Step S1, as shown in FIG. 1, when active positioning functions of train 1 and train 2 are normal, trackside MWSP equipment (ATP interval protection equipment) calculates train movement authority based on active positioning information and a principle of the moving block, a train rear end of the train 2 is sent to the train 1 as a movement authority terminal, and onboard MVTP equipment of the train 1 calculates a safety protection curve based on the received movement authority and assists in train running.

[0029] Step S2, as shown in FIG. 2, when onboard MVTP equipment of the train 2 has a fault and loses positioning, the trackside MWSP equipment calculates the target distance and the speed code based on information about occupancy of a section (a track section 1) in which a non-positioning envelope of the train 1 is located, a permanent speed limit (80km/h) of a line, information about occupancy of a section (a track section 5) in which the train 2 is located, a state of trackside signaling equipment, and sends a speed code of each section to the train 1 out of position, and the train 1 is converted into a train under control of the quasi-moving block mode: the train 1 is away from the train 2 when running in the track section 1, so that the MWSP uses the permanent speed limit 80km/h of the line in the track section 1 as the speed code to be sent to the train 1; and a distance between the train 1 and the train 2 is shorter when the train 1 runs in a track section 2, the MWSP uses an entrance of the track section 5 as a target distance protection point and calculates the speed code as 60km/h to be sent to the train 1, and onboard equipment of the train 1 monitors a speed based on the received speed code during train running and assists in the train running.

[0030] Step S3, as shown in FIG. 3, when the train 1 is re-positioned during running in the quasi-moving block mode, the onboard MVTP equipment of the train 1 automatically switches back to a control mode of the moving block, namely, step S1 in the flow.

[0031] The above is an introduction to the method embodiments. The following further describes the solutions in the present invention through system embodiments.

[0032] The present invention provides a CBTC system based on interval protection and heterogeneous redundancy. The system includes an onboard ATP subsystem MVTP that is compatible with modes of the movement authority and speed code, a trackside ATP interval protection subsystem MWSP that can perform self-adaptive operations of a moving block mode and a quasi-moving block mode based on an active train positioning state, and a communication subsystem DCS between the train and the trackside. Hardware of the MVTP and MWSP is one set of safety platforms, and the MVTP preferentially uses the movement authority information received from the trackside. The target distance (ATP mode) or speed code information (RM mode) is considered when the movement authority information is not available, and safe train running protection is performed based on the received available information. The MWSP automatically identifies and uses a corresponding block mode based on a positioning state, a driving mode, and other information sent by the train, and calculates the movement authority (of a train that is positioned in ATP mode), the target distance (of a train that is not positioned in ATP mode) or a speed code (of a train in an RM mode) in a corresponding block mode. A calculation result is sent to onboard equipment of a corresponding train through train-ground communication.

[0033] It may be clearly understood by a person skilled in the art that, for a detailed working process of the above module, reference may be made to the corresponding process in the foregoing method embodiments for the purpose of convenient and brief description. Details are not described herein.

[0034] The electronic device in the present invention includes a central processing unit (CPU), which can perform various proper actions and processing based on computer program instructions stored in a read-only memory (ROM) or computer program instructions loaded from a storage unit to a random access memory (RAM). The RAM also stores various programs and data that are necessary for device operation. The CPU, ROM, and RAM are connected to each other via a bus. An input/output (I/O) interface is also connected to the bus.

[0035] Several components in the device are connected to the I/O interface, including: input units, such as a keyboard, a mouse, and the like; output units, such as various monitors, speakers, and the like; storage units, such as a disk, an optical disc, and the like; and communication units, such as a network card, a modem, a wireless communication transceiver, and the like. 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.

[0036] The processing unit performs the methods and processing described above, such as the method in the present invention. For example, in some embodiments, the method in the present invention may be implemented as computer software programs that are tangibly included in a machine-readable medium, such as a storage unit. In some embodiments, some or all of the computer programs may be loaded and/or installed onto the device via the ROM and/or communication unit. When the computer programs are loaded into the RAM and executed by the CPU, one or more of the steps of the method in the present invention described above can be performed. Alternatively, in other embodiments, the CPU may be configured to perform the method in the present invention in any other proper manner (for example, with the help of firmware).

[0037] Functions described above in the specification can be performed, at least in part, by one or more hardware logic components. For example, hardware logic components that can be used as examples include, unlimitedly, 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 the like.

[0038] Program code for implementing the method in the present invention may be written in any combination of one or more programming languages. The program code may be provided to processors or controllers of general-purpose computers, specialized computers, or other programmable data processing devices, so that when the program code is executed by the processors or controllers, functions/operations specified in flowcharts and/or block diagrams are implemented. The program code can be executed entirely on a machine, partially on the machine, partially on the machine and partially on a remote machine as a separate software package, or entirely on the remote machine or server.

[0039] In the context of the present invention, a machine-readable medium may be a tangible medium that may contain or store programs for use by or in combination with an instruction execution system, apparatus, or device. The machine-readable medium may be either a machine-readable signal medium or 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 proper combination thereof. A more specific example of the machine-readable storage medium includes an electrical connection based on one or more wires, a portable computer disk, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or flash memory), an optical fiber, a portable compact disk read-only memory (CD-ROM), an optical storage device, a magnetic storage device, or any proper combination thereof.

[0040] The foregoing descriptions are merely implementations of the present invention, but are not intended to limit the protection scope of the present invention. Any equivalent variation or replacement readily figured out by a person skilled in the art within the technical scope disclosed in the present invention 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.

Claims

1. A CBTC system based on interval protection and heterogeneous redundancy, wherein the CBTC system comprises a communication subsystem DCS and an onboard ATP subsystem MVTP and a trackside ATP interval protection subsystem MWSP that communicate with the communication subsystem DCS separately;
   the onboard ATP subsystem MVTP receives movement authority information from the trackside ATP interval protection subsystem MWSP, and receives, when the movement authority information is unavailable, information about a target distance or speed code to perform safe train running protection; and the trackside ATP interval protection subsystem MWSP automatically identifies and uses a corresponding block mode based on information sent by the onboard ATP subsystem MVTP, calculates movement authority and the target distance or speed code in the corresponding block mode, and sends a calculation result to a corresponding train.

2. The CBTC system based on interval protection and heterogeneous redundancy according to claim 1, wherein the onboard ATP subsystem MVTP is compatible with modes of the movement authority and the speed code.

3. The CBTC system based on interval protection and heterogeneous redundancy according to claim 1, wherein the trackside ATP interval protection subsystem MWSP performs self-adaptive operations of a moving block mode and a quasi-moving block mode based on an active train positioning state.

4. The CBTC system based on interval protection and heterogeneous redundancy according to claim 1, wherein the movement authority is calculated for a train with a normal active positioning function and in ATP mode.

5. The CBTC system based on interval protection and heterogeneous redundancy according to claim 1, wherein the target distance is calculated for a train with an abnormal active positioning function and in ATP mode.

6. The CBTC system based on interval protection and heterogeneous redundancy according to claim 1, wherein the speed code is calculated for a train in an RM mode.

7. The CBTC system based on interval protection and heterogeneous redundancy according to claim 1, wherein both the onboard ATP subsystem MVTP and the trackside ATP interval protection subsystem MWSP are a set of safety platforms.

8. An implementation method for the CBTC system based on interval protection and heterogeneous redundancy according to claim 1, specifically comprising the following steps:

step S1, when an active train positioning function is normal, calculating, by the trackside ATP interval protection subsystem MWSP, the movement authority based on a principle of moving block, and when the active train positioning function is abnormal and a train is out of position, performing step S2, otherwise performing step S1 again;
step S2, calculating, by the trackside ATP interval protection subsystem MWSP, the target distance or speed code based on information about a train out of position, and performing step S3; and
step S3, returning to step S1 if the train out of position is re-positioned during running in a quasi-moving block mode.

9. The implementation method according to claim 8, wherein the movement authority in step S1 is received by the onboard ATP subsystem MVTP, and calculation of a safety protection curve is calculated, to assist in train running.

10. The implementation method according to claim 8, wherein the information about the train out of position in step S2 comprises information about occupancy of a section in which a non-positioning envelope corresponding to the train out of position is located, information about permanent or temporary speed limit setting of a line, information about occupancy of adjacent trains or sections on the line, state information of trackside signaling equipment, and driving mode information of the train.

11. The implementation method according to claim 10, wherein the trackside signaling equipment comprises a signal, a switch, a platform emergency closing button, and a platform door.

12. The implementation method according to claim 8, wherein the target distance in step S3 is calculated for a train in ATP mode.

13. The implementation method according to claim 8, wherein the speed code in step S3 is calculated for a train in an RM mode.

14. The implementation method according to claim 8, wherein the target distance or speed code in step S2 is received by the onboard ATP subsystem MVTP, and speed monitoring is performed on a running train out of position, to assist in train running.

15. An electronic device, comprising a memory and a processor, wherein a computer program is stored in the memory, and when the processor executes the program, the method according to any one of claims 8 to 14 is implemented.

16. A computer-readable storage medium, storing a computer program, wherein when the program is executed by a processor, the method according to any one of claims 8 to 14 is implemented.

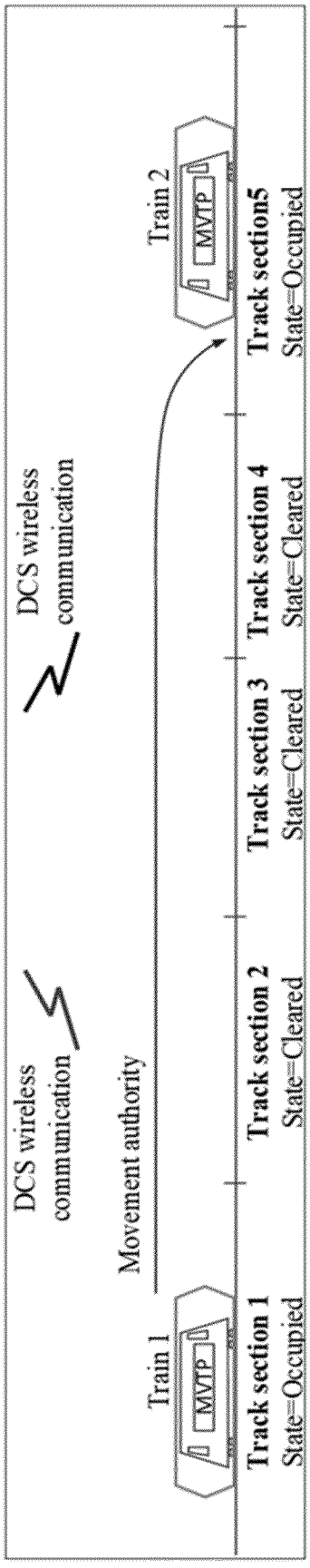
DCS wireless communication
DCS wireless communication
Movement authority
Train 1
MVTP
Train 2
MVTP
Track section 1
State=Occupied
Track section 2
State=Cleared
Track section 3
State=Cleared
Track section 4
State=Cleared
Track section5
State=Occupied

FIG. 1

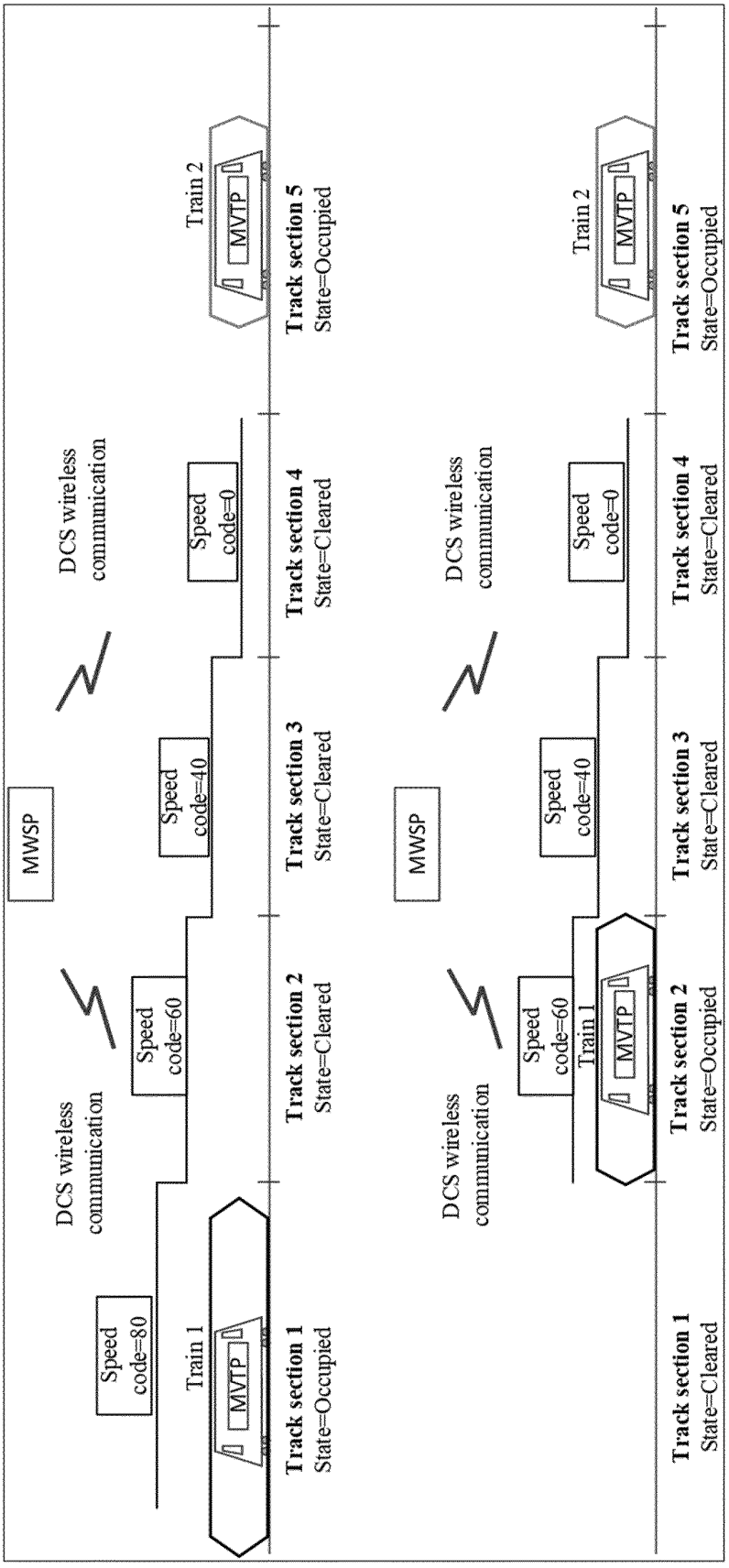
MWSP
DCS wireless communication
Speed code=80
Speed code=60
Speed code=40
Speed code=0
Train 1
Train 2
MVTP
Track section 1
State=Occupied
Track section 2
State=Cleared
Track section 3
State=Cleared
Track section 4
State=Cleared
Track section 5
State=Occupied

FIG. 2

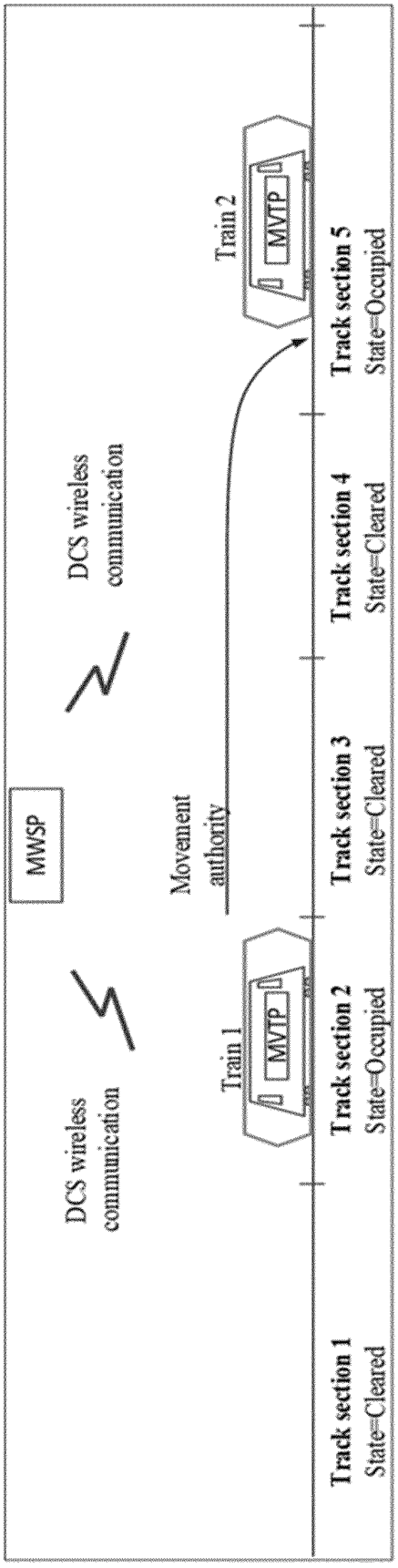
MWSP
DCS wireless communication
DCS wireless communication
Movement authority
Train 1
MVTP
Train 2
MVTP
Track section 1
State=Cleared
Track section 2
State=Occupied
Track section 3
State=Cleared
Track section 4
State=Cleared
Track section 5
State=Occupied

FIG. 3

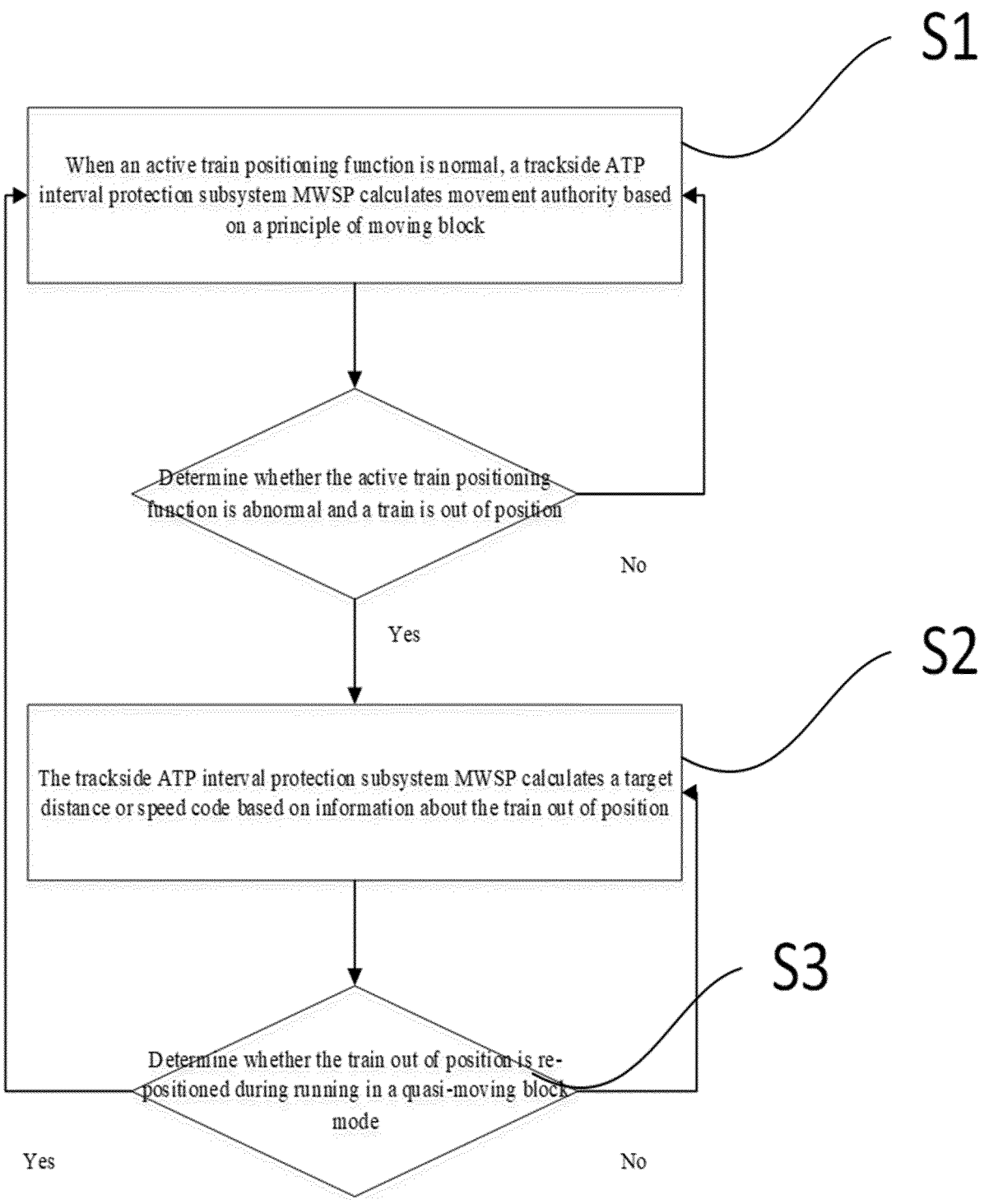
S1
When an active train positioning function is normal, a trackside ATP interval protection subsystem MWSP calculates movement authority based on a principle of moving block
Determine whether the active train positioning function is abnormal and a train is out of position
No
Yes
S2
The trackside ATP interval protection subsystem MWSP calculates a target distance or speed code based on information about the train out of position
S3
Determine whether the train out of position is re-positioned during running in a quasi-moving block mode
Yes
No

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2023/132187

A. CLASSIFICATION OF SUBJECT MATTER

B61L27/00(2022.01)i; B61L25/00(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: B61L 27 , B61L 23

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNTXT, DWPI, VEN, ENTXTC, ENTXT, CNKI: 列车, 闭塞模式, 间隔, 距离, 速度, 运行模式, 移动授权, 识别, 自动防护, CBTC, ATP, MWSP, MA, interval protection, train, mode, speed, distance

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	CN 116946222 A (CASCO SIGNAL LTD.) 27 October 2023 (2023-10-27) claims 1-16	1-16
A	CN 113264086 A (CASCO SIGNAL LTD.) 17 August 2021 (2021-08-17) description, paragraphs [0006]-[0053], and figures 1-5	1-16
A	CN 103707904 A (BEIJING TRAFFIC CONTROL TECHNOLOGY CO., LTD.) 09 April 2014 (2014-04-09) entire document	1-16
A	CN 104149821 A (CASCO SIGNAL LTD.) 19 November 2014 (2014-11-19) entire document	1-16
A	CN 106741013 A (TRAFFIC CONTROL TECHNOLOGY CO., LTD.) 31 May 2017 (2017-05-31) entire document	1-16
A	CN 109941318 A (CASCO SIGNAL LTD.) 28 June 2019 (2019-06-28) entire document	1-16

☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
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"P" document published prior to the international filing date but later than the priority date claimed
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 April 2024	**22 April 2024**
Name and mailing address of the ISA/CN **China National Intellectual Property Administration (ISA/CN)** **China No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088**	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 2022)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2023/132187

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KR 101041963 B1 (KIM, H. S. et al.) 16 June 2011 (2011-06-16) entire document	1-16

Form PCT/ISA/210 (second sheet) (July 2022)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2023/132187

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
CN 116946222 A	27 October 2023	None	
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CN 106741013 A	31 May 2017	None	
CN 109941318 A	28 June 2019	None	
KR 101041963 B1	16 June 2011	None	

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