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(54) ROLL DETECTOR, TRAIN CONTROL SYSTEM

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(57) **ABSTRACT**

A roll detector mounted on a train includes: a sensor that detects a movement of the train while the train is not in operation with an on-board controller being inactive, the on-board controller controlling an action of the train; and a roll sensor that determines whether or not the train has rolled on the basis of a result of the detection by the sensor, and performs train protection when determining that the train has rolled.

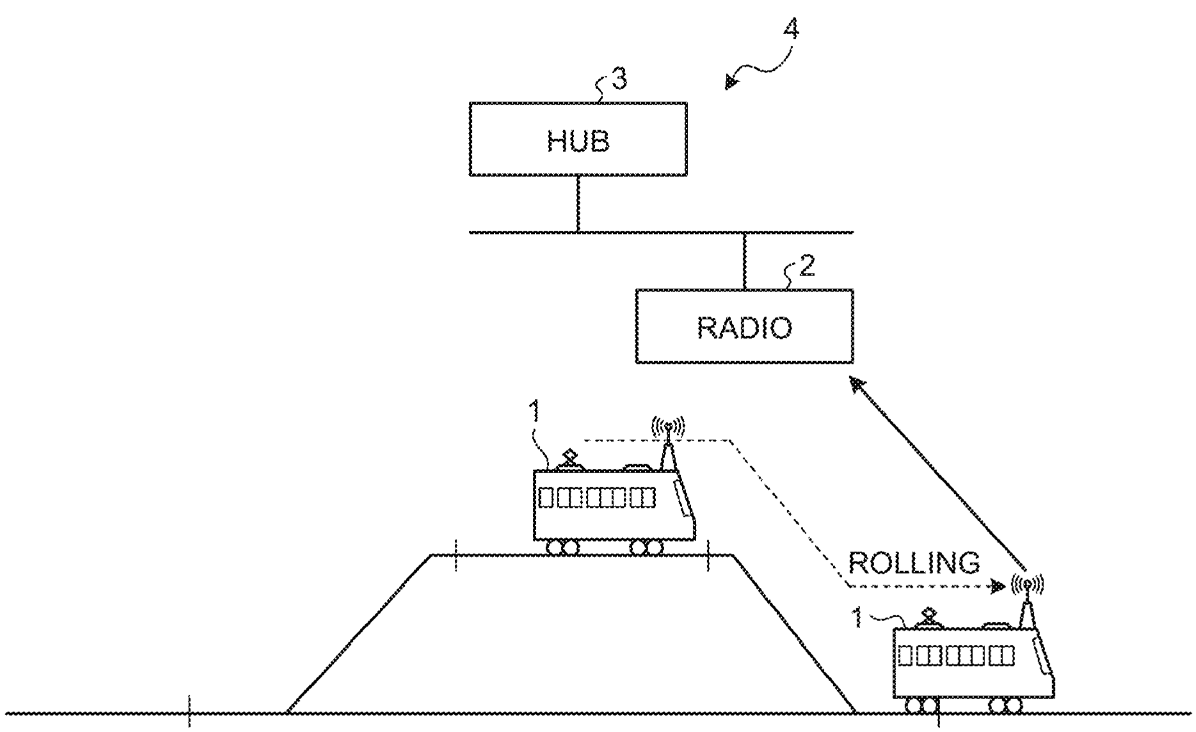


FIG.1

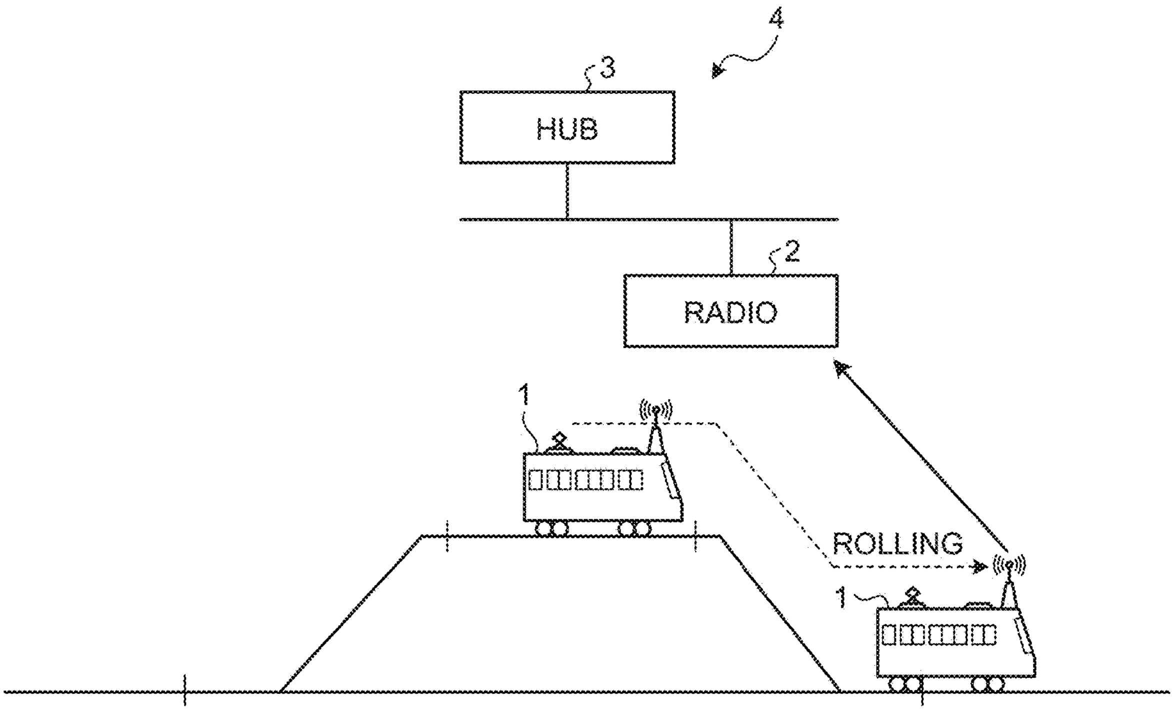

4
3
HUB
2
RADIO
1
ROLLING
1

FIG.2

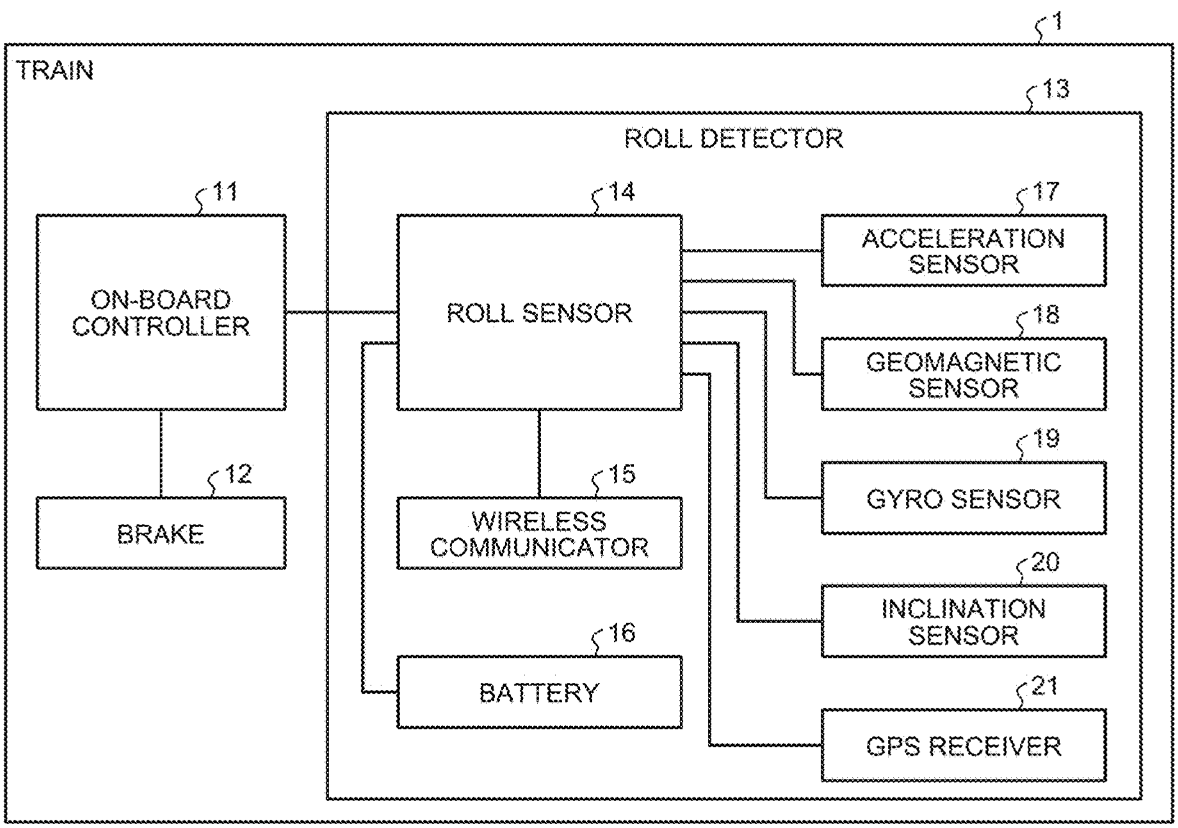

1
TRAIN
13
ROLL DETECTOR
11
ON-BOARD CONTROLLER
14
ROLL SENSOR
17
ACCELERATION SENSOR
18
GEOMAGNETIC SENSOR
12
BRAKE
15
WIRELESS COMMUNICATOR
19
GYRO SENSOR
20
INCLINATION SENSOR
16
BATTERY
21
GPS RECEIVER

FIG.3

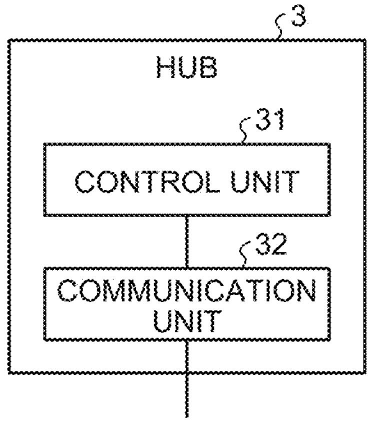

3
HUB
31
CONTROL UNIT
32
COMMUNICATION UNIT

FIG.4

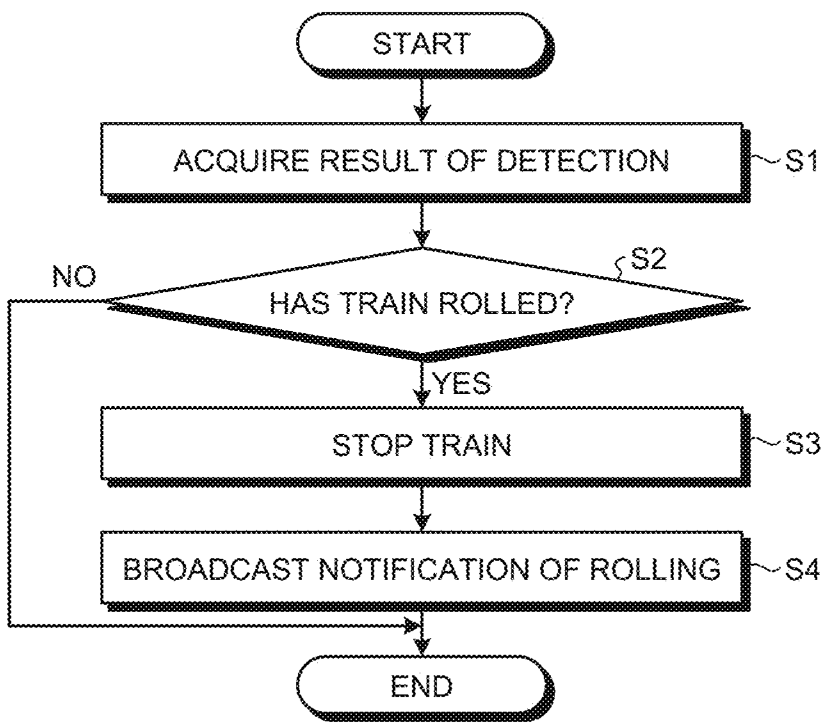

START
ACQUIRE RESULT OF DETECTION
S1
S2
NO
HAS TRAIN ROLLED?
YES
STOP TRAIN
S3
BROADCAST NOTIFICATION OF ROLLING
S4
END

FIG.5

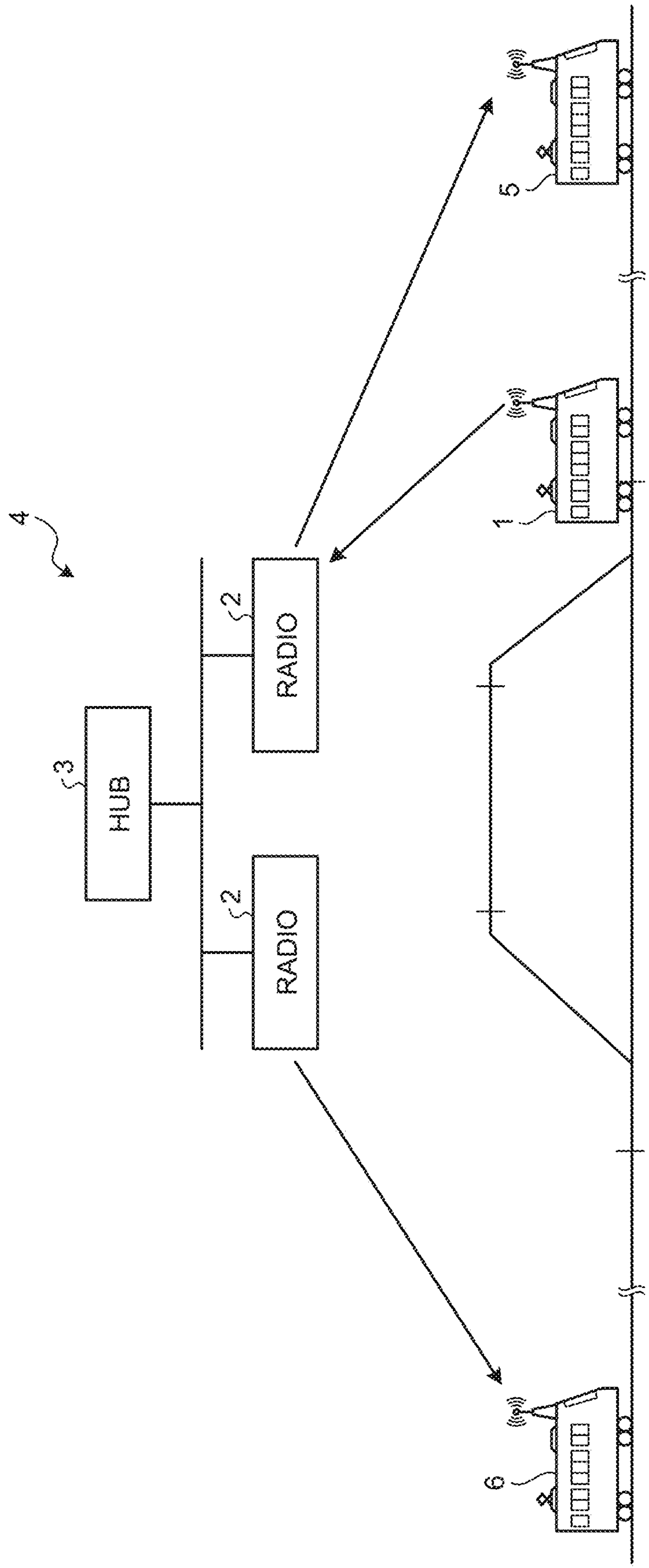


FIG.6

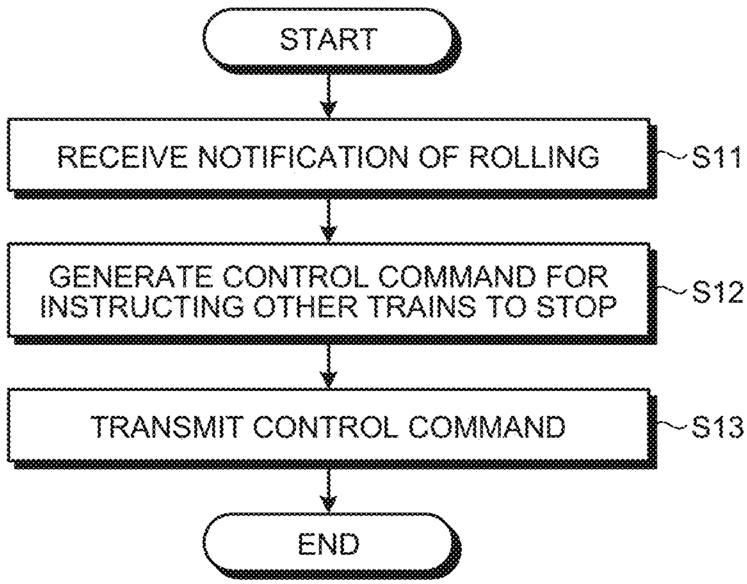


FIG.7

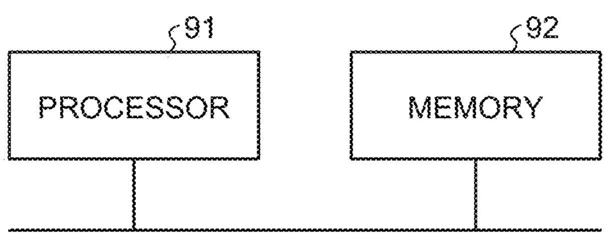


FIG.8

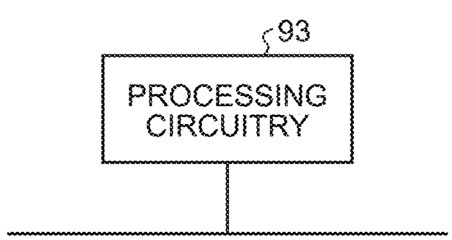


FIG.9

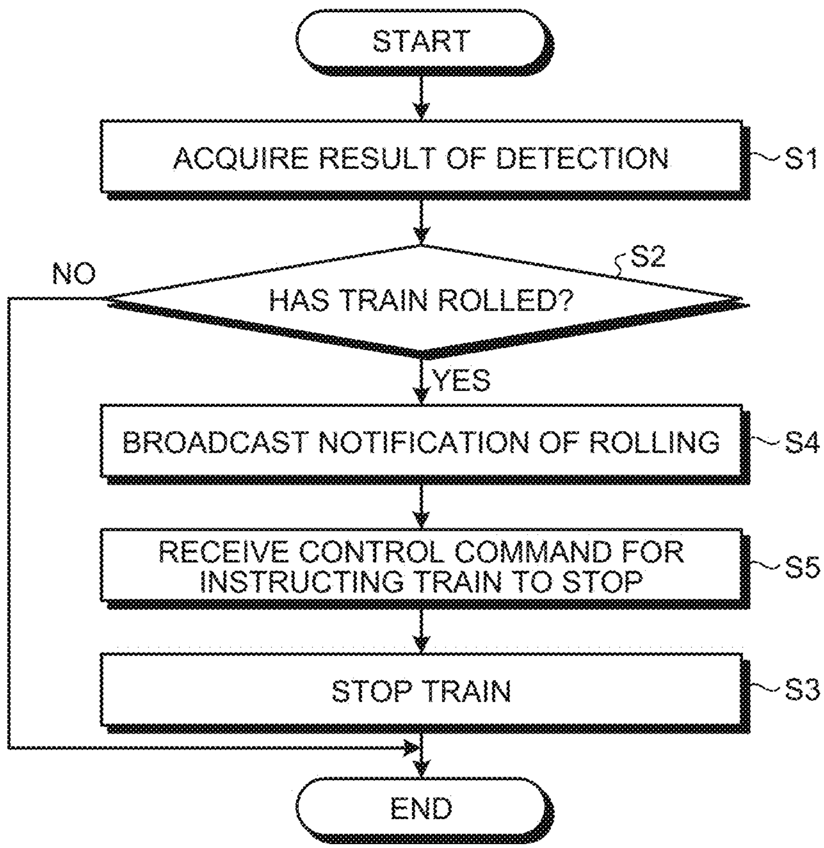

START
ACQUIRE RESULT OF DETECTION
S1
S2
NO
HAS TRAIN ROLLED?
YES
BROADCAST NOTIFICATION OF ROLLING
S4
RECEIVE CONTROL COMMAND FOR INSTRUCTING TRAIN TO STOP
S5
STOP TRAIN
S3
END

FIG.10

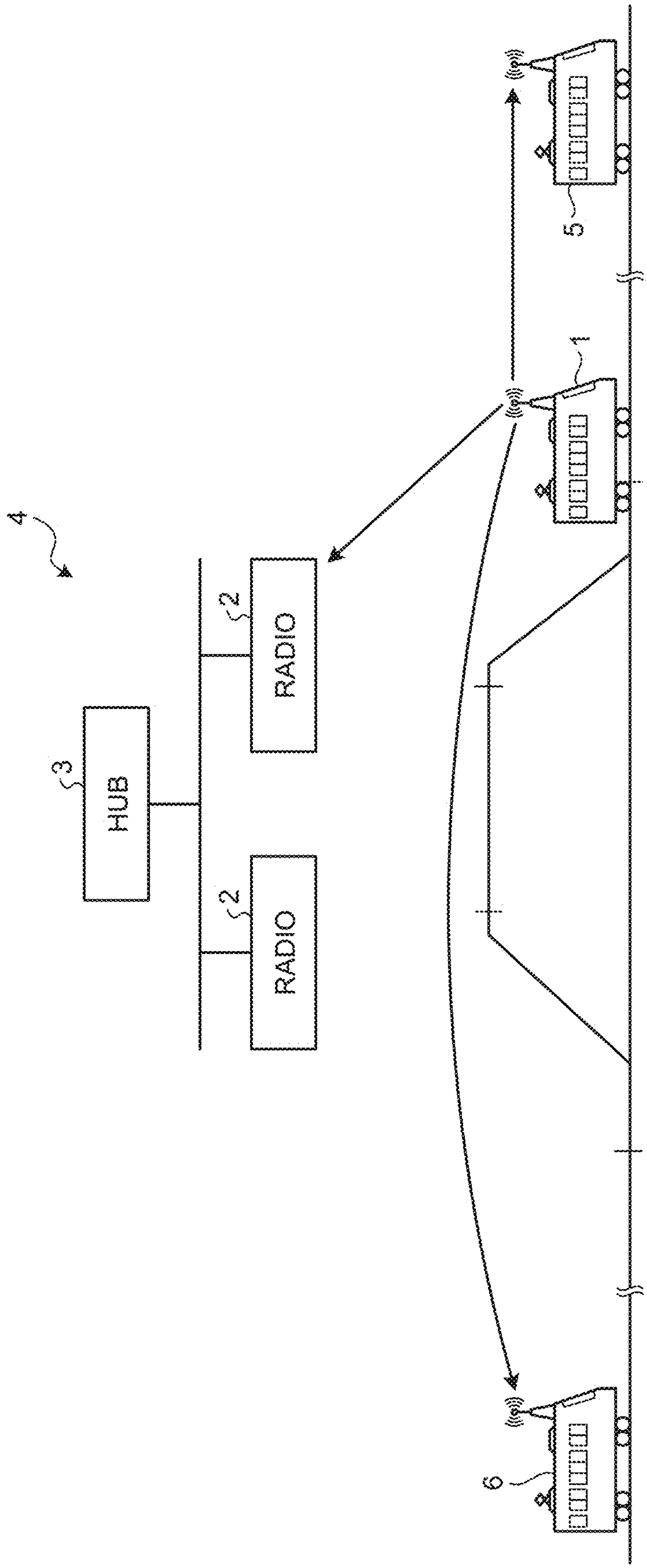


FIG.11

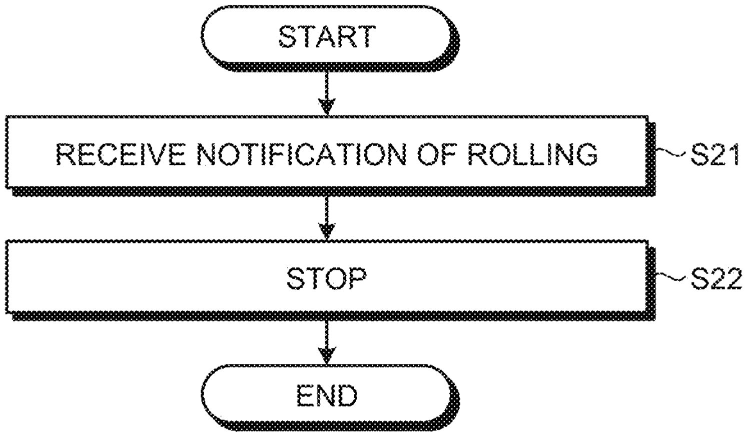

START
RECEIVE NOTIFICATION OF ROLLING
S21
STOP
S22
END

FIG.12

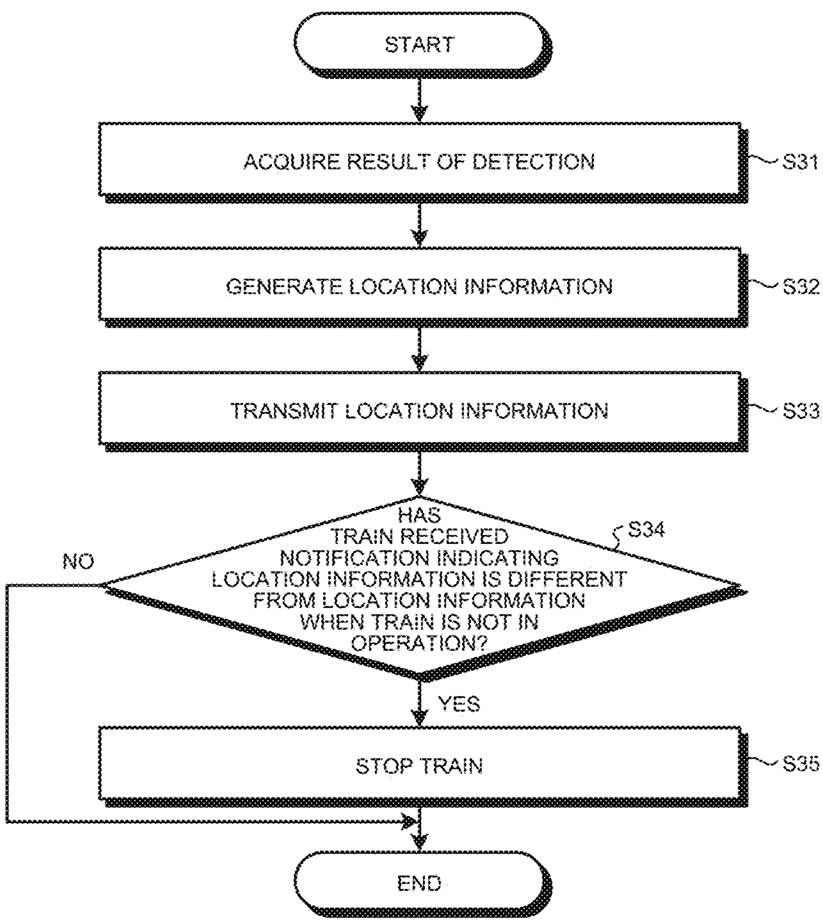

START
ACQUIRE RESULT OF DETECTION
S31
GENERATE LOCATION INFORMATION
S32
TRANSMIT LOCATION INFORMATION
S33
HAS TRAIN RECEIVED NOTIFICATION INDICATING LOCATION INFORMATION IS DIFFERENT FROM LOCATION INFORMATION WHEN TRAIN IS NOT IN OPERATION?
S34
NO
YES
STOP TRAIN
S35
END

FIG.13

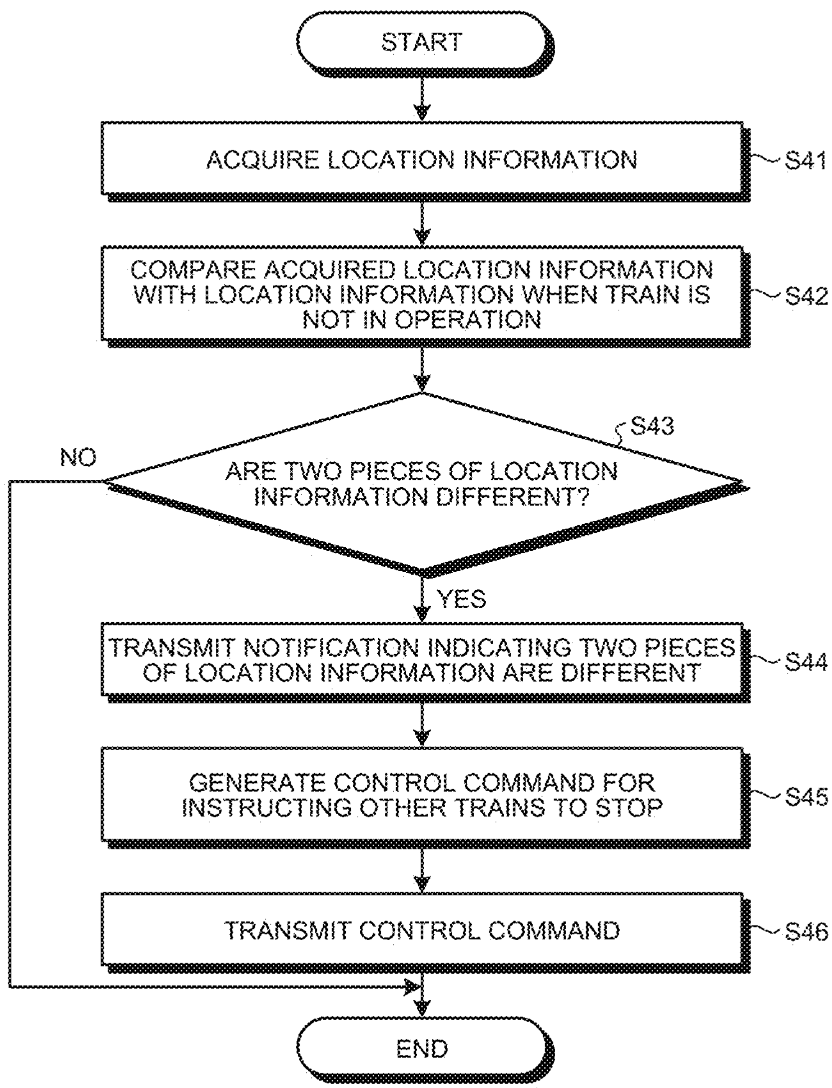
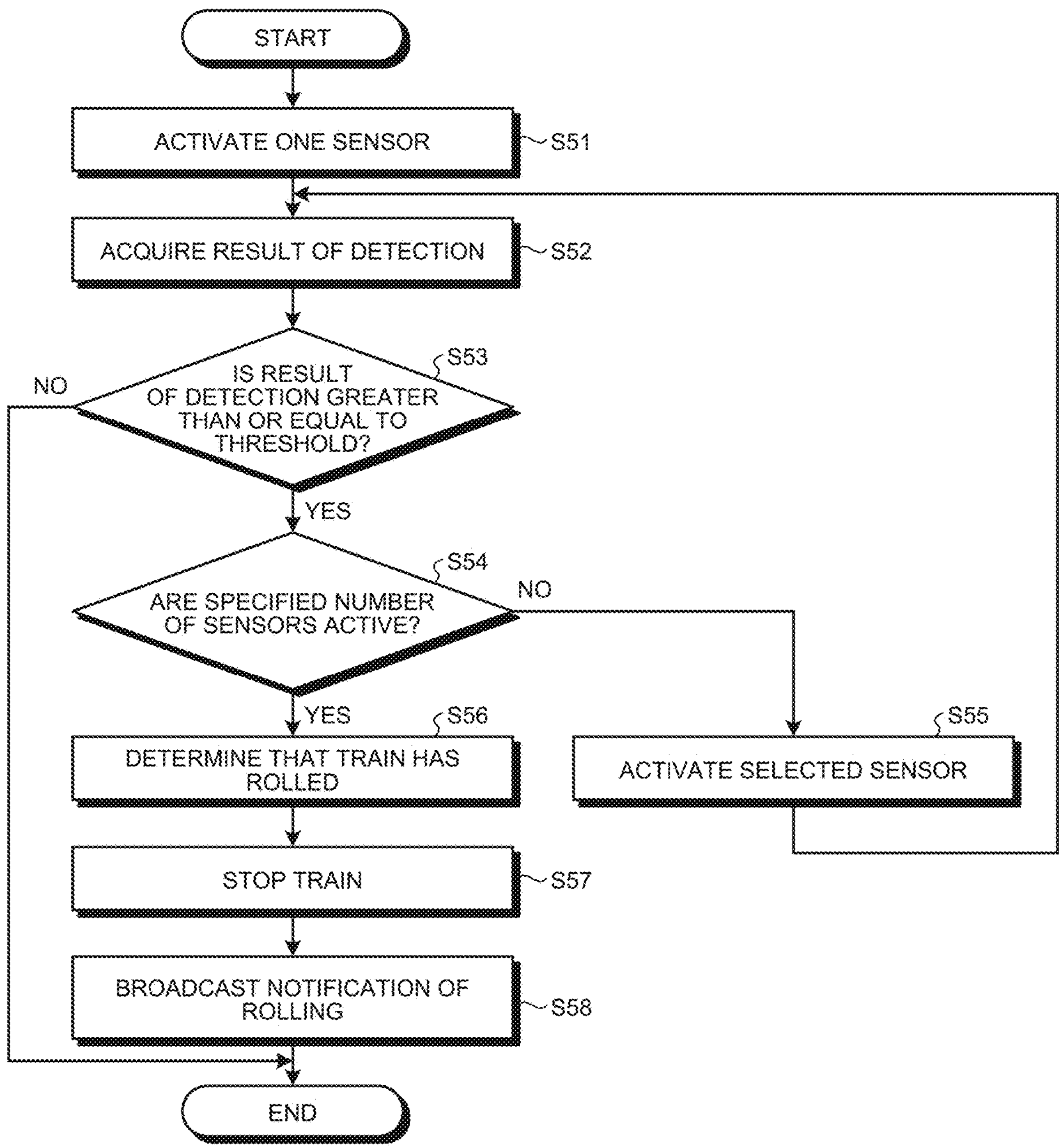

START
ACQUIRE LOCATION INFORMATION
S41
COMPARE ACQUIRED LOCATION INFORMATION WITH LOCATION INFORMATION WHEN TRAIN IS NOT IN OPERATION
S42
S43
ARE TWO PIECES OF LOCATION INFORMATION DIFFERENT?
NO
YES
TRANSMIT NOTIFICATION INDICATING TWO PIECES OF LOCATION INFORMATION ARE DIFFERENT
S44
GENERATE CONTROL COMMAND FOR INSTRUCTING OTHER TRAINS TO STOP
S45
TRANSMIT CONTROL COMMAND
S46
END

FIG.14


START
ACTIVATE ONE SENSOR
S51
ACQUIRE RESULT OF DETECTION
S52
IS RESULT OF DETECTION GREATER THAN OR EQUAL TO THRESHOLD?
S53
NO
YES
ARE SPECIFIED NUMBER OF SENSORS ACTIVE?
S54
NO
YES
DETERMINE THAT TRAIN HAS ROLLED
S56
ACTIVATE SELECTED SENSOR
S55
STOP TRAIN
S57
BROADCAST NOTIFICATION OF ROLLING
S58
END

ROLL DETECTOR, TRAIN CONTROL SYSTEM

FIELD

[0001] The present invention relates to a roll detector mounted on a train, a train control system, and a roll detection method.

BACKGROUND

[0002] An on-board controller mounted on a train transmits locational information indicating the location of the train to a hub during operation of the train. The on-board controller is turned off when the train is not in operation, and thus does not transmit the locational information to the hub. Therefore, when the train that is not in operation has rolled, the hub cannot know the location of the train having rolled so that an accident may occur due to the train having rolled. In order for the hub to know the location of the train that is not in operation, the train needs to have the on-board controller operating at all times and transmit the locational information to the hub. However, having the on-board controller operating at all times on the train that is not in operation is not preferable in terms of energy saving.

[0003] Patent Literature 1 discloses a technique in which, on a berthed train with an on-board controller being stopped, a radio transmits information measured by a sensor to a ground safety control unit, and the ground safety control unit determines whether or not the berthed train has rolled on the basis of the information measured by the sensor. In a vehicle control system described in Patent Literature 1, the berthed train reduces or prevents an increase in power consumption by stopping the on-board controller while operating the sensor and the radio.

CITATION LIST

Patent Literature

[0004] Patent Literature 1: Japanese Patent Application Laid-open No. 2016-137731

SUMMARY

Technical Problem

[0005] However, there has been a problem in the vehicle control system described in Patent Literature 1 that, when it is determined that the train has rolled, the ground safety control unit can perform train protection on another train in operation and stop the train, but cannot perform train protection to control the action on the train that has rolled while the on-board controller is stopped.

[0006] The present invention has been made in view of the above, and an object of the present invention is to provide a roll detector that can perform train protection when a train equipped with the roll detector rolls, while reducing or preventing an increase in power consumption.

Solution to Problem

[0007] To solve the above problems and achieve the object the present invention relates to a roll detector mounted on a train. The roll detector includes: a sensor to detect a movement of the train while the train is not in operation with an on-board controller being inactive, the on-board controller controlling an action of the train; and a roll sensor to determine whether or not the train has rolled on the basis of a result of the detection by the sensor, and perform train protection when determining that the has rolled.

Advantageous Effects of Invention

[0008] According to the present invention, the roll detector has an effect of being able to perform train protection when the train equipped with the roll detector rolls, while reducing or preventing an increase in power consumption.

BRIEF DESCRIPTION OF DRAWINGS

[0009] FIG. **1** is a diagram illustrating an example of the configuration of a train control system according to a first embodiment.

[0010] FIG. **2** is a block diagram illustrating an example of the configuration of a train according to the first embodiment.

[0011] FIG. **3** is a block diagram illustrating an example of the configuration of a hub according to the first embodiment.

[0012] FIG. **4** is a flowchart illustrating an operation in which a roll detector according to the first embodiment detects rolling of the train.

[0013] FIG. **5** is a diagram illustrating another example of the configuration of the train control system according to the first embodiment.

[0014] FIG. **6** is a flowchart illustrating an operation when the hub according to the first embodiment receives a notification of rolling from the train.

[0015] FIG. **7** is a diagram illustrating an example of a case where processing circuitry of the roll detector according to the first embodiment includes a processor and a memory.

[0016] FIG. **8** is a diagram illustrating an example of a case where the processing circuitry of the roll detector according to the first embodiment includes dedicated hardware.

[0017] FIG. **9** is a flowchart illustrating another operation in which the roll detector according to the first embodiment detects rolling of the train.

[0018] FIG. **10** is a diagram illustrating an example of the configuration of the train control system according to a second embodiment.

[0019] FIG. **11** is a flowchart illustrating an action of other trains according to the second embodiment.

[0020] FIG. **12** is a flowchart illustrating an operation in which the roll detector according to a third embodiment detects rolling of the train.

[0021] FIG. **13** is a flowchart illustrating an operation when the hub according to the third embodiment receives locational information from the train.

[0022] FIG. **14** is a flowchart illustrating an operation in which the roll detector according to a fourth embodiment detects rolling of the train.

DESCRIPTION OF EMBODIMENTS

[0023] A roll detector, a train control system, and a roll detection method according to embodiments of the present invention will now be described in detail with reference to the drawings. Note that the present invention is not limited to the embodiments.

First Embodiment

[0024] FIG. **1** is a diagram illustrating an example of the configuration of a train control system **4** according to a first embodiment of the present invention. The train control system **4** includes a train **1**, a radio **2**, and a hub **3**.

[0025] During operation, the train **1** periodically transmits its own locational information to the hub **3** via the radio **2**, and travels in accordance with a control command received from the hub **3** via the radio **2**. Also, the train **1** performs train protection when detecting rolling of itself while not in operation such as while being berthed or detained. Rolling refers to a movement of a stopped train due to the gradient of a track or the like without using the power of the train. Train protection is to notify a train of danger and to stop the train safely in the event of a failure that requires stopping the train. Note that in the first embodiment, the number of cars on the train **1** is not limited. The train **1** may include one car, that is, one car operating by itself.

[0026] The radio **2** is installed on the ground and relays wireless communication between the train **1** and the hub **3**. The radio **2** transmits signals such as the locational information received from the train **1** to the hub **3**, and transmits signals such as the control command received from the hub **3** to the train **1**. Note that although FIG. **1** illustrates an example where there is one radio **2**, two or more of the radios **2** may be connected to one hub **3**.

[0027] The hub **3** is a ground apparatus installed on the ground. The hub **3** acquires the locational information from the train **1** and controls the operation of the train **1** such as the course of the train **1**. The hub **3** also controls the interval between trains when a plurality of trains is present within the jurisdiction of the hub **3**.

[0028] The configuration of the train **1** will be described. FIG. **2** is a block diagram illustrating an example of the configuration of the train **1** according to the first embodiment. The train **1** includes an on-board controller **11**, a brake **12**, and a roll detector **13**. The train **1** illustrated in FIG. **2** includes components related to an operation of detecting rolling and train protection after detecting rolling in the first embodiment, and the description of general components is omitted. The on-board controller **11** controls the action of the train **1** and controls running and stopping of the train **1**. The brake **12** decelerates or stops the train **1** under the control of the on-board controller **11**.

[0029] The roll detector **13** detects rolling of the train **1** while the train **1** is not in operation. On the train **1** that is in operation, the on-board controller **11** and the brake **12** are active, but the roll detector **13** is inactive. Moreover, on the train **1** that is not in operation, the roll detector **13** is active, but the on-board controller **11** and the brake **12** are inactive. With the components being activated in such a manner, the train **1** can reduce or prevent an increase in power consumption while not in operation, as compared to a case where the on-board controller **11** is active while the train **1** is not in operation. However, when train protection is to be performed while the train **1** is not in operation, the roll detector **13** can start-up the on-board controller **11** and allow the on-board controller **11** to control the train **1**. The roll detector **13** includes a roll sensor **14**, a wireless communicator **15**, a battery **16**, an acceleration sensor **17**, a geomagnetic sensor **18**, a gyro sensor **19**, an inclination sensor **20**, and a Global Positioning System (GPS) receiver **21**. Note that when the acceleration sensor **17**, the geomagnetic sensor **18**, the gyro sensor **19**, the inclination sensor **20**, and the GPS receiver **21** are not to be distinguished from one another, they may be collectively or individually referred to as sensors. The sensors detect a movement of the train **1** while the train **1** is not in operation with the on-board controller **11** being inactive.

[0030] The roll sensor **14** determines whether or not the train **1** has rolled on the basis of a result of detection by at least one of the acceleration sensor **17**, the geomagnetic sensor **18**, the gyro sensor **19**, the inclination sensor **20**, and the GPS receiver **21**. Specifically, the roll sensor **14** determines that the train **1** has rolled when the result of detection by at least one of the sensors indicates a movement of the train **1** while the train **1** is not in operation. The roll sensor **14** performs train protection when determining that the train **1** has rolled. Note that the roll sensor **14** may determine whether or not the train **1** has rolled using the results of detection by all the sensors, or may determine whether or not the train **1** has rolled using the results of detection by some of the sensors. Moreover, the roll detector **13** may include only some of the sensors illustrated in FIG. **2** instead of including all the sensors illustrated in FIG. **2**. In this case, the roll sensor **14** determines whether or not the train **1** has rolled using the result of detection by one or more of the sensors included in the roll detector **13**.

[0031] When the roll sensor **14** determines that the train **1** has rolled, the wireless communicator **15** transmits a signal of train protection under the control of the roll sensor **14**. The signal of train protection is, for example, a notification indicating that the train **1** has rolled as described later. The wireless communicator **15** also receives a signal transmitted from the hub **3** via the radio **2**. The wireless communicator **15** is, for example, a radio that performs specified low-power radio communication.

[0032] The battery **16** supplies power to the roll sensor **14**, the wireless communicator **15**, the acceleration sensor **17**, the geomagnetic sensor **18**, the gyro sensor **19**, the inclination sensor **20**, and the GPS receiver **21**. The roll detector **13** needs to detect rolling of the train **1** while the train is not in operation and thus needs to operate even in a state in which, when the train **1** is an electric train, a pantograph (not shown) of the train **1** is lowered, or power is not supplied from an overhead wire. Therefore, the roll detector **13**, specifically, each component of the roll detector **13** excluding the battery **16**, is driven by the battery **16**. Note that FIG. **2** illustrates an example where the battery **16** is connected only to the roll sensor **14**, and the roll sensor **14** supplies power to each component, but the battery **16** may directly supply power to each component. Alternatively, the battery **16** may be placed outside the roll detector **13**.

[0033] The acceleration sensor **17** is a sensor that detects the acceleration of the train **1** and detects a movement of the train **1** on the basis of the acceleration of the train **1**. The geomagnetic sensor **18** is a sensor that detects the geomagnetism around the train **1** and detects a movement of the train **1** on the basis of a change in the geomagnetism around the train **1**. The gyro sensor **19** is a sensor that detects a change in the rotation or orientation of the train **1** and the like, that is, a change in the attitude of the train **1**, and detects a movement of the train **1** on the basis of the change in the attitude of the train **1**. The inclination sensor **20** is a sensor that detects a change in the inclination of the train **1** and detects a movement of the train **1** on the basis of the change in the inclination of the train **1**. The GPS receiver **21** is a sensor that detects the location of the train **1** and detects a movement of the train **1** on the basis of the location of the train **1**. Note that the sensors illustrated in FIG. **2** are examples, and the roll detector **13** may further include a digital camera (not shown) or the like for use as a sensor. Also, the roll detector **13** does not need to include some of the sensors illustrated in FIG. **2**. The train **1** may use some of the sensors included in the roll detector **13**, such as the GPS receiver **21**, during operation.

[0034] The configuration of the hub **3** will be described. FIG. **3** is a block diagram illustrating an example of the configuration of the hub **3** according to the first embodiment. The hub **3** includes a control unit **31** and a communication unit **32**. While the train **1** is in operation, the control unit **31** controls the operation of the train **1** by using the locational information of the train **1** or the like. Moreover, when having acquired a notification indicating that the train **1** has rolled from the train **1**, the control unit **31** instructs other trains within the jurisdiction of the hub **3** to stop, as train protection of the train **1**. The communication unit **32** outputs a signal such as the locational information of the train **1** received from the radio **2** to the control unit **31**, and transmits a signal such as a control command acquired from the control unit **31** to the radio **2**. The communication between the communication unit **32** and the radio **2** may be wired communication or wireless communication.

[0035] Next, an operation will be described in which the roll detector **13** of the train **1** detects rolling of the train **1** in the train control system **4**. FIG. **4** is a flowchart illustrating the operation in which the roll detector **13** according to the first embodiment detects rolling of the train **1**. As described above, the roll detector **13** performs the operation while the train **1** is berthed or detained and not in operation. In the roll detector **13**, the roll sensor **14** acquires a result of detection from each sensor when the train **1** stops operating (step S**1**).

[0036] The roll sensor **14** determines whether or not the train **1** has rolled on the basis of the result of detection by each sensor (step S**2**). The roll sensor **14** for example compares the result of detection by each sensor with a corresponding threshold that is set for each sensor to determine a movement of the train **1**. The roll sensor **14** determines that the train **1** has moved, that is, has rolled, while not in operation when the number, of the results of detection by the sensors greater than or equal to the corresponding thresholds, is larger than or equal to a preset number. The roll sensor **14** determines that the train **1** has not moved, that is, has not rolled, while not in operation when the number, of the results of detection by the sensors greater than or equal to the corresponding thresholds, is smaller than a preset number. The roll sensor **14** uses the results of detection by the plurality of sensors to be able to prevent false detection of rolling and improve the accuracy of detecting rolling.

[0037] The roll sensor **14** ends the processing if determined that the train **1** has not rolled (No in step S**2**). If determined that the train **1** has rolled (Yes in step S**2**), the roll sensor **14** performs train protection to start-up the on-board controller **11** and instruct the on-board controller **11** to control the brake **12** and stop the train **1** (step S**3**). The on-board controller **11** is started-up by the control of the roll sensor **14**, controls the brake **12** in accordance with the instruction by the roll sensor **14**, and stops the train **1**. At this time, upon being started-up by the control of the roll sensor **14**, the on-board controller **11** raises the pantograph (not shown) and receives power supply from the overhead wire. As a result, the train **1** can perform an action similar to that during operation under the control of the on-board controller **11**. Note that on the train **1**, the roll sensor **14** may perform control from raising the pantograph (not shown) up to receiving power supply from the overhead wire, and then start-up the on-board controller **11**. The roll detector **13** of the first embodiment is also applicable to a case where power is supplied by the third rail system.

[0038] Moreover, as train protection, the roll sensor **14** causes the wireless communicator **15** to broadcast a notification indicating that the train **1** has rolled (step S**4**). Hereinafter, the notification indicating that the train **1** has rolled may be referred to as a notification of rolling. The roll sensor **14** may switch the order of step S**3** and step S**4**, or may execute step S**3** and step S**4** at the same time. The roll detector **13** periodically repeats the operation of the flowchart illustrated in FIG. **4**.

[0039] Next, the operation of the hub **3** that receives the notification of rolling from the train **1** will be described. FIG. **5** is a diagram illustrating another example of the configuration of the train control system **4** according to the first embodiment. The train control system **4** illustrated in FIG. **5** is obtained by adding a second radio **2** and trains **5** and **6** to the train control system **4** illustrated in FIG. **1**. The trains **5** and **6** are trains that are present within the jurisdiction of the hub **3**. Each of the trains **5** and **6** may have a configuration similar to that of the train **1**, or need not include the roll detector **13** as long as the trains **5** and **6** can travel in accordance with a control command from the hub **3**. Similar to the train **1**, the trains **5** and **6** may each include one car, that is, one car operating by itself. The trains **5** and **6** are collectively referred to as other trains. FIG. **6** is a flowchart illustrating the operation when the hub **3** according to the first embodiment receives the notification of rolling from the train **1**. In the hub **3**, the control unit **31** receives the notification of rolling from the train **1** via the radio **2** and the communication unit **32** (step S**11**). The control unit **31** generates a control command for instructing the other trains within its jurisdiction to stop (step S**12**). The control unit **31** transmits the control command generated to the other trains within its jurisdiction via the communication unit **32** and the radio **2** (step S**13**). The other trains that have received the control command from the hub **3** stop in accordance with the control command.

[0040] As described above, the train **1** stops and causes the other trains to stop when determining that the train **1** has rolled. The train **1** can thus avoid an accident caused by itself when it has rolled such as a collision between trains.

[0041] Next, a hardware configuration of the roll detector **13** will be described. In the roll detector **13**, the wireless communicator **15** is a communication device that performs specified low-power radio communication. The battery **16** is a small battery that can drive the components of the roll detector **13** excluding the battery **16** while the train **1** is not in operation. The acceleration sensor **17**, the geomagnetic sensor **18**, the gyro sensor **19**, the inclination sensor **20**, and the GPS receiver **21** are measuring instruments that measure target phenomena of the sensors. The roll sensor **14** is implemented by processing circuitry. The processing circuitry may include a memory and a processor executing programs stored in the memory, or may include dedicated hardware.

[0042] FIG. **7** is a diagram illustrating an example of the case where the processing circuitry of the roll detector **13**

according to the first embodiment includes a processor and a memory. When the processing circuitry includes a processor 91 and a memory 92, each function of the processing circuitry of the roll detector 13 is implemented by software, firmware, or a combination of software and firmware. The software or firmware is described as programs and stored in the memory 92. The processing circuitry implements each function by the processor 91 reading and executing the programs stored in the memory 92. That is, the processing circuitry includes the memory 92 for storing the programs that result in the execution of the processing of the roll detector 13. It can also be said that these programs cause a computer to execute the procedure and method related to the roll detector 13.

[0043] Here, the processor 91 may be a central processing unit (CPU), a processing unit, an arithmetic unit, a microprocessor, a microcomputer, a digital signal processor (DSP), or the like. The memory 92 corresponds to, for example, a non-volatile or volatile semiconductor memory such as a random access memory (RAM), a read only memory (ROM), a flash memory, an erasable programmable ROM (EPROM), or an electrically EPROM (EEPROM (registered trademark)), a magnetic disk, a flexible disk, an optical disk, a compact disc, a mini disc, a digital versatile disc (DVD), or the like.

[0044] FIG. 8 is a diagram illustrating an example of the case where the processing circuitry of the roll detector 13 according to the first embodiment includes dedicated hardware. When the processing circuitry includes dedicated hardware, processing circuitry 93 illustrated in FIG. 8 corresponds to a single circuit, a complex circuit, a programmed processor, a parallel-programmed processor, an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), or a combination of those, for example. The functions of the roll detector 13 may be implemented individually or collectively by the processing circuitry 93.

[0045] Note that the functions of the roll detector 13 may be implemented partly by dedicated hardware and partly by software or firmware. The processing circuitry can thus implement the aforementioned functions by the dedicated hardware, software, firmware, or a combination of these.

[0046] Next, a hardware configuration of the hub 3 will be described. In the hub 3, the communication unit 32 is a communication device that performs wired communication or wireless communication with the radio 2. The control unit 31 is implemented by processing circuitry. The processing circuitry has the configuration illustrated in FIG. 7 or 8 as with the processing circuitry included in the roll detector 13.

[0047] According to the first embodiment described above, when determining that the train 1 has rolled on the basis of the results of detection by the sensors while the train 1 is not in operation, the roll detector 13 performs train protection to stop the train 1, notify the hub 3 that the train has rolled, and cause the other trains to stop by the control of the hub 3. The on-board controller 11 is stopped while the train 1 is berthed or detained and not in operation, and when the roll detector 13 determines that the train 1 has rolled, the roll detector 13 starts-up the on-board controller 11 so that the on-board controller 11 performs the operation to stop the train 1. Therefore, the roll detector 13 can reduce or prevent an increase in power consumption of the train 1 while at the same time perform train protection on the train 1 immediately and on the other trains in operation when the train 1 equipped with the roll detector 13 has rolled.

[0048] Moreover, the train 1 can determine whether or not rolling has occurred without depending on equipment on the ground such as the hub 3. The train 1 thus does not require equipment such as a track circuit or a ground element on the ground, so that the place where the train 1 is berthed or detained is not limited.

[0049] Note that when determining that the train 1 has rolled, the roll sensor 14 may stop the train 1 after receiving the control command from the hub 3 instead of immediately stopping the train 1. In this case, the control unit 31 of the hub 3 generates a control command for instructing all trains within its jurisdiction including the train 1 to stop in the operation of step S12 illustrated in the flowchart of FIG. 6. FIG. 9 is a flowchart illustrating another operation in which the roll detector 13 according to the first embodiment detects rolling of the train 1. If "Yes" in step S2, the roll sensor 14 causes the wireless communicator 15 to broadcast a notification of rolling as train protection (step S4). Upon receiving a control command for instructing all trains within the jurisdiction of the hub 3 to stop from the hub 3 via the radio 2 and the wireless communicator 15 (step S5), the roll sensor 14 performs train protection to start-up the on-board controller 11 and instruct the on-board controller 11 to control the brake 12 and stop the train 1 (step S3). In this case as well, the roll detector 13 or the train 1 can reduce or prevent an increase in power consumption of the train 1 while at the same time perform train protection on the train 1 and on the other trains in operation when the train 1 equipped with the roll detector 13 has rolled.

Second Embodiment

[0050] In the first embodiment, the other trains within the jurisdiction of the hub 3 stop on the basis of the control command from the hub 3. In a second embodiment, the other trains directly receive a notification of rolling from the train 1 and stop. Differences from the first embodiment will be described.

[0051] FIG. 10 is a diagram illustrating an example of the configuration of the train control system 4 according to the second embodiment. The configurations of the train 1 and the hub 3 of the second embodiment are similar to the configurations of the train 1 and the hub 3 of the first embodiment. The train control system 4 illustrated in FIG. 10 differs from the train control system 4 of the first embodiment illustrated in FIG. 5 in terms of the path for transmitting signals to the trains 5 and 6. As with the first embodiment, the roll detector 13 of the second embodiment performs the operation in the flowchart of the first embodiment illustrated in FIG. 4. Here, when the roll detector 13 on the train 1 determines that the train 1 has rolled as described above (Yes in step S2), the roll detector 13 broadcasts the notification of rolling (step S4). That is, when determining that the train 1 has rolled, the roll detector 13 of the train 1 broadcasts the notification of rolling to the other trains that are within the jurisdiction of the hub 3 and managed by the hub 3. The other trains can thus receive the notification of rolling directly from the train 1.

[0052] The action of the trains 5 and 6, that is, the other trains, will be described. FIG. 11 is a flowchart illustrating the action of the other trains according to the second embodiment. The other trains receive the notification of rolling from train 1 (step S21). The other trains stop upon recognizing that the train **1** around the other trains has rolled from the content of the notification of rolling (step S**22**). It is assumed that the other trains are in operation with the on-board controllers being active. Therefore, the other trains can immediately perform the processing to stop upon receiving the notification of rolling from the train **1**. In the second embodiment, the hub **3** also receives the notification of rolling from the train **1** via the radio **2**. Therefore, the hub **3** need not generate and transmit the control command for instructing the other trains within its jurisdiction to stop. The hub **3** may generate and transmit the control command for instructing the other trains within its jurisdiction to stop when the range of jurisdiction is wider than the communication area of the wireless communicator **15** of the roll detector **13**.

[0053] According to the second embodiment described above, the other trains in the train control system **4** stop when receiving the notification of rolling from the train **1**. As a result, the train control system **4** can obtain the effect similar to that of the first embodiment, and the other trains can stop faster than in the first embodiment.

Third Embodiment

[0054] In a third embodiment, the train **1** periodically transmits locational information to the hub **3** and performs train protection when receiving, from the hub **3**, a notification indicating that the locational information is different from the location at the time the train is not in operation. Differences from the first embodiment will be described.

[0055] The configurations of the train **1** and the hub **3** of the third embodiment are similar to the configurations of the train **1** and the hub **3** of the first embodiment. The configuration of the train control system **4** of the third embodiment is also similar to the configuration of the train control system **4** of the first embodiment illustrated in FIGS. **1** and **5**, but the communication between the train **1** and the hub **3** is two-way communication. Note that as a general function, the hub **3** is assumed to acquire the locational information of the train **1** at the time the train is not in operation from the train **1**, and know the location of the train **1** at the time the train is not in operation.

[0056] FIG. **12** is a flowchart illustrating an operation in which the roll detector **13** according to the third embodiment detects rolling of the train **1**. In the roll detector **13**, the roll sensor **14** acquires a result of detection from each sensor when the train **1** stops operating (step S**31**). The roll sensor **14** identifies the current location of the train **1** on the basis of the result of detection acquired from each sensor, and generates locational information (step S**32**). The roll sensor **14** can generate the locational information using the result of detection by the GPS receiver **21**. The roll sensor **14** causes the wireless communicator **15** to transmit the locational information (step S**33**). The roll sensor **14** determines that the train **1** has rolled if having received, from the hub **3**, a notification indicating that the locational information of the train **1** transmitted is different from the locational information of the train **1** at the time the train is not in operation (Yes in step S**34**), and performs train protection to start-up the on-board controller **11** and instruct the on-board controller **11** to control the brake **12** and stop the train **1** (step S**35**). The roll sensor **14** ends the processing if having not received, from the hub **3**, the notification indicating that the locational information of the train **1** transmitted is different from the locational information of the train **1** at the time the train is not in operation within a specified time after transmitting the locational information (No in step S**34**).

[0057] FIG. **13** is a flowchart illustrating an operation when the hub **3** according to the third embodiment receives the locational information from the train **1**. In the hub **3**, the control unit **31** acquires the locational information of the train **1** from the train **1** via the radio **2** and the communication unit **32** (step S**41**). The control unit **31** compares the locational information of the train **1** acquired with the locational information of the train **1** at the time the train is not in operation (step S**42**). For example, the control unit **31** calculates a difference between the locational information of the train **1** acquired and the locational information of the train **1** at the time the train is not in operation, compares an absolute value of the difference calculated with a specified threshold, and determines whether or not the two pieces of the locational information are different. If the absolute value of the difference is larger than the specified threshold, the control unit **31** determines that the two pieces of the locational information being compared are different (Yes in step S**43**), and transmits a notification indicating that the two pieces of the locational information are different to the train **1** via the communication unit **32** and the radio **2** (step S**44**). The control unit **31** further generates a control command for instructing the other trains within its jurisdiction to stop (step S**45**). The control unit **31** transmits the control command generated to the other trains within its jurisdiction via the communication unit **32** and the radio **2** (step S**46**). The other trains that have received the control command from the hub **3** stop in accordance with the content of the control command. If the absolute value of the difference is less than or equal to the specified threshold, the control unit **31** determines that the two pieces of the locational information are the same (No in step S**43**), and ends the processing.

[0058] According to the third embodiment described above, the roll detector **13** periodically transmits the locational information to the hub **3** and makes the determination about rolling on the basis of the notification from the hub **3**. The hub **3** performs the comparison processing in the determination about rolling, whereby the roll detector **13** can obtain the effect similar to that of the first embodiment and can also reduce the processing load and power consumption as compared with the first embodiment.

Fourth Embodiment

[0059] In the first embodiment, the roll detector **13** causes the plurality of sensors to be active at the same time and determines whether or not the train **1** has rolled on the basis of the results of detection by the sensors. In a fourth embodiment, the roll detector **13** activates one sensor first and, if a result of detection obtained by the one sensor indicates a movement of the train **1**, activates another sensor to acquire a result of detection from the other sensors and determine whether or not the train **1** has rolled. Differences from the first embodiment will be described.

[0060] The configurations of the train **1** and the hub **3** of the fourth embodiment are similar to the configurations of the train **1** and the hub **3** of the first embodiment. The configuration of the train control system **4** of the fourth embodiment is also similar to the configuration of the train control system **4** of the first embodiment illustrated in FIGS. **1** and **5**. In the fourth embodiment, the operation of the roll detector **13** up to determining whether or not the train **1** has rolled is different from that of the first embodiment.

[0061] FIG. **14** is a flowchart illustrating an operation in which the roll detector **13** according to the fourth embodiment detects rolling of the train **1**. When the train **1** stops operating, the roll sensor **14** activates one preset sensor (step S**51**) and acquires results of detection from all sensors that are active (step S**52**). The roll sensor **14** compares the results of detection, which are acquired, with thresholds that are set for the active sensors to determine a movement of the train **1**. If any of the results of detection is less than the threshold (No in step S**53**), the roll sensor **4** ends the processing. If all the results of detection acquired from the active sensors are greater than or equal to the corresponding thresholds (Yes in step S**53**), the roll sensor **14** determines whether or not a specified number of the sensors are active (step S**54**). If not the specified number of the sensors are active (No in step S**54**), the roll sensor **14** selects one of the sensors that are not active and activates the sensor selected (step S**55**). The roll sensor **14** returns to step S**52** and repeats the above operation.

[0062] If the specified number of the sensors are active (Yes in step S**54**), the roll sensor **14** determines that the train **1** has rolled (step S**56**). The roll sensor **14** performs train protection to start-up the on-board controller **11** and instruct the on-board controller **11** to control the brake **12** and stop the train **1** (step S**57**). Moreover, as train protection, the roll sensor **14** causes the wireless communicator **15** to broadcast a notification indicating that the train **1** has rolled (step S**58**). The operations of steps S**57** and S**58** are similar to the operations of steps S3 and S4 in the flowchart of the first embodiment illustrated in FIG. **4**.

[0063] Note that the example of the flowchart illustrated in FIG. **14** illustrates the case where the roll detector **13** increases the number of active sensors one by one, but the number of sensors activated is not limited to this example. For example, the roll detector **13** may first activate one sensor and, if a result of detection is greater than or equal to a threshold, may activate all the remaining sensors that have not been activated.

[0064] Alternatively, the roll detector **13** may first activate a plurality of sensors and, if each result of detection is greater than or equal to a threshold, may further select a plurality of sensors from the sensors that have not been activated and increase the number of sensors to be activated. Thus, the roll sensor **14** activates one or more sensors among the plurality of sensors and, when acquiring from the one or more sensors a result of detection indicating a movement of the train **1**, that is, a result of detection greater than or equal to the threshold, activates a sensor that has not been activated among the plurality of sensors to determine whether or not the train **1** has rolled on the basis of a result of detection by the sensor activated. The roll sensor **14** may, for example, activate the acceleration sensor **17**, the geomagnetic sensor **18**, and the gyro sensor **19** first and then activate the GPS receiver **21** when the results of detection by the sensors are all greater than or equal to the thresholds.

[0065] In the fourth embodiment, the hub **3** and the other trains perform the operations similar to that in the first or second embodiment.

[0066] According to the fourth embodiment described above, the roll detector **13** activates some of the sensors first and, when the result of detection is greater than or equal to the threshold, that is, the result of detection includes the content indicating a movement, increases the number of sensors to be activated to determine whether or not the train **1** has rolled. As a result, the roll detector **13** can obtain the effect similar to that of the first embodiment and can also reduce power consumption as compared with the first embodiment while preventing false detection of rolling.

[0067] The configuration illustrated in the above embodiment merely illustrates an example of the content of the present invention, and can thus be combined with another known technique or partially omitted and/or modified without departing from the scope of the present invention.

REFERENCE SIGNS LIST

[0068] **1**, **5**, **6** train; **2** radio; **3** hub; **4** train control system; **11** on-board controller; **12** brake; **13** roll detector; **14** roll sensor; **15** wireless communicator; **16** battery; **17** acceleration sensor; **18** geomagnetic sensor; **19** gyro sensor; **20** inclination sensor; **21** GPS receiver; **31** control unit; **32** communication unit.

1. A roll detector mounted on a train, the roll detector comprising:

a sensor to detect a movement of the train while the train is not in operation with an on-board controller being inactive, the on-board controller controlling an action of the train; and

a roll sensor to determine whether or not the train has rolled on the basis of a result of the detection by the sensor, and perform train protection when determining that the has rolled.

2. The roll detector according to claim **1**, wherein

the roll sensor determines that the has rolled when the result of the detection by the sensor indicates the movement of the train.

3. The roll detector according to claim **1**, comprising

a wireless communicator, wherein

as the train protection, the roll sensor causes the wireless communicator to broadcast a notification indicating that the train has rolled.

4. The roll detector according to claim **3**, wherein

when the roll sensor receives an instruction to stop the train via the wireless communicator from a hub that receives the notification, the roll sensor starts-up the on-board controller and instructs the on-board controller to stop the train.

5. The roll detector according to claim **2**, comprising

a wireless communicator, wherein

as the train protection, the roll sensor transmits locational information of the train from the wireless communicator to a hub and, when receiving a notification from the hub that receives the locational information via the wireless communicator, starts-up the on-board controller to instruct the on-board controller to stop the train, the notification indicating that the locational information of the train transmitted is different from locational information of the train at the time the train is not in operation.

6. The roll detector according to claim **3**, wherein

the wireless communicator performs specified low-power radio communication.

7. The roll detector according to claim **1**, wherein

as the train protection, the roll sensor starts-up the on-board controller and instructs the on-board controller to stop the train.

8. The roll detector according to claim **1**, wherein

the roll detector includes a plurality of the sensors, and

the roll sensor determines whether or not the train has rolled on the basis of results of detection by the plurality of the sensors.

9. The roll detector according to claim **1**, wherein

the roll detector includes a plurality of the sensors, and

the roll sensor activates one or more sensors among the plurality of the sensors and, when acquiring a result of detection indicating a movement of the train from the one or more sensors, activates a sensor that is not activated among the plurality of the sensors to determine whether or not the train has rolled on the basis of a result of detection by the sensor activated.

10. The roll detector according to claim **1**, wherein

the roll detector is driven by a battery.

11. A train control system comprising:

a roll detector to determine whether or not a train has rolled on the basis of a result of detection by a sensor while the train is not in operation with an on-board controller being inactive, and perform train protection when determining that the train has rolled, the sensor detecting a movement of the train, and the on-board controller controlling an action of the train; and

a hub to control the operation of the train, wherein

as the train protection, the roll detector broadcasts a notification indicating that the has rolled,

the hub instructs the roll detector to stop the train when receiving the notification, and

the roll detector starts-up the on-board controller and instructs the on-board controller to stop the train, when receiving the instruction to stop the train from the hub.

12. The train control system according to claim **11**, wherein

when receiving the notification, the hub transmits a control command to another train whose operation is controlled by the hub, the control command instructing the other train to stop.

13. The train control system according to claim **11**, wherein

the roll detector transmits the notification to another train whose operation is controlled by the hub.

14. A train control system comprising:

a roll detector to determine whether or not a train has rolled on the basis of a result of detection by a sensor while the train is not in operation with an on-board controller being inactive, and perform train protection when determining that the train has rolled, the sensor detecting a movement of the train, and the on-board controller controlling an action of the train; and

a hub to control the operation of the train, wherein

as the train protection, the roll detector starts-up the on-board controller to instruct the on-board controller to stop the train, and broadcasts a notification indicating that the train has rolled.

15-21. (canceled)

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