(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 154 946 A1

(12) EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
**29.03.2023 Bulletin 2023/13**

(21) Application number: **20943530.4**

(22) Date of filing: **30.06.2020**

(51) International Patent Classification (IPC):
***A62C 37/50*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
**A62C 37/50**

(86) International application number:
**PCT/CN2020/099332**

(87) International publication number:
**WO 2022/000279 (06.01.2022 Gazette 2022/01)**

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**
Designated Extension States:
**BA ME**
Designated Validation States:
**KH MA MD TN**

(71) Applicant: **Siemens Aktiengesellschaft**
**80333 München (DE)**

(72) Inventors:
- **LI, Changlong**
**Qingdao, Shandong 266000 (CN)**
- **QIU, Wenqing**
**Laixi, Shandong 266600 (CN)**
- **YU, Qi**
**Nanjing, Jiangsu 211100 (CN)**

(74) Representative: **Isarpatent**
**Patent- und Rechtsanwälte Barth**
**Charles Hassa Peckmann & Partner mbB**
**Friedrichstrasse 31**
**80801 München (DE)**

# (54) FIRE EXTINGUISHING SYSTEM, SERVER, FIRE-FIGHTING ROBOT, AND FIRE EXTINGUISHING METHOD

(57) A fire extinguishing system (10), a server (30), a fire-fighting robot (40), and a fire extinguishing method (400). The system comprises: a fire source detection apparatus (20), which is arranged at a fixed position in a monitoring area, and is used for detecting a fire source in the monitoring area; the server (30), which is used for determining a fire source position on the basis of detection parameters provided by the fire source detection apparatus (20), determining a fire extinguishing position of the fire-fighting robot (40) on the basis of the fire source position, and sending a first robot control command that includes the fire extinguishing position; and the fire-fighting robot (40), which is used for moving to the fire extinguishing position on the basis of the first robot control command and executing fire extinguishing operations against the fire source, without using fire-fighting monitors in a fixed deployment, thereby reducing costs, improving the fire extinguishing efficiency, reducing the power loss of the fire-fighting robot, and improving the security of the fire-fighting robot.

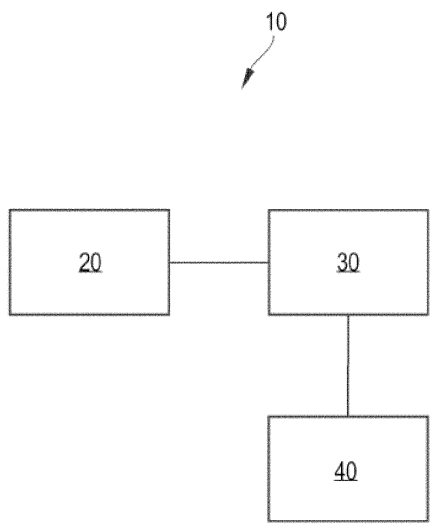


Fig. 1

EP 4 154 946 A1

## Description

### Technical Field

**[0001]** The present invention relates to the technical field of robots, and in particular to a fire extinguishing system, a server, a fire-fighting robot and a fire extinguishing method.

### Background Art

**[0002]** In the case of a fire, the earlier the fire is found and put out, the safer it is. An automatic fire extinguishing system can be deployed in unattended operating environments such as garages and factory buildings to find and put out a fire. The automatic fire extinguishing system usually has the fire source detection function, the fire source locating function and the fire extinguishing function. The fire source detection function is used to detect an occurrence of a fire, the fire source locating function is used to calculate the specific position of the fire source, and the fire extinguishing function is used to extinguish the fire.

**[0003]** More and more fire-fighting robots are used in the fire-fighting field. How to use fire-fighting robots in an automatic fire extinguishing system is a hot research topic. Currently, there are two major methods of establishing an automatic fire extinguishing system. The first method is to use a fire-fighting cannon having the infrared laser fire detection function, and the fire-fighting cannon is fixed in a high position (for example, on a high wall or a column) and can automatically detect a fire and put it out. The second method is to place a fire-fighting cannon on a patrol inspection robot, and the patrol inspection robot continuously inspects a whole workplace along a specified path. In the case of a fire, the fire-fighting cannon on the patrol inspection robot will put it out.

**[0004]** Disadvantage of the first method: The range of a fire-fighting cannon is usually limited (for example, only 30 meters to 50 meters) and one fire-fighting cannon can cover only a small area, and thus more fire-fighting cannons need to be deployed in a large environment, resulting in a huge cost. Disadvantage of the second method: A patrol inspection robot needs to move continuously, so the power is often insufficient. In addition, when a patrol inspection robot is charged, there exists a time window in which the patrol inspection robot is unable to perform a fire-fighting operation, which leads to potential safety hazards.

### Summary of the Invention

**[0005]** Embodiments of the present invention provide a fire extinguishing system, a server, a fire-fighting robot and a fire extinguishing method.

**[0006]** The technical solutions adopted for embodiments of the present invention are as follows:
A fire extinguishing system, comprises:

a fire source detection apparatus, arranged in a fixed position in a monitored area to detect any fire source in the monitored area;
a server, used to determine a fire source position based on detection parameters provided by the fire source detection apparatus, determine the fire extinguishing position of a fire-fighting robot based on the fire source position, and send a first robot control command containing the fire extinguishing position;
a fire-fighting robot, used to move to the fire extinguishing position based on the first robot control command and perform a fire extinguishing operation on the fire source.

**[0007]** It can be seen that fixedly deployed fire-fighting cannons are no longer adopted in embodiments of the present invention, and thus the cost is reduced and the fire extinguishing efficiency is improved. In addition, the fire-fighting robot in embodiments of the present invention does not need to move continuously, and thus, the power loss of the fire-fighting robot is reduced, a time window in which a fire-fighting operation is unable to be performed is avoided, hence improved fire-fighting safety.

**[0008]** In one embodiment, the fire source detection apparatus comprises:

an adjustable pan/tilt/zoom (PTZ) dome;
a camera, arranged on the adjustable PTZ dome to detect any fire source;
a ranging sensor, arranged on the adjustable PTZ dome or the camera to detect a distance from the camera to the fire source;
a communication module, used to send the detection parameters, wherein the detection parameters include at least one of the following:
the distance; a pitch angle of the camera; a yaw angle of the camera; a fire scene picture.

**[0009]** Therefore, embodiments of the present invention further provide a specific structure for the fire source detection apparatus to facilitate its implementation. In addition, detection parameters help to determine a fire source position and a fire scene range.

**[0010]** In one embodiment, the server is configured to receive a two-dimensional navigation map of the monitored area from the fire-fighting robot and determine the coordinates (x, y) of the fire source in the two-dimensional navigation map based on the distance, the pitch angle of the camera and the yaw angle of the camera, wherein:

$$x = X - D * \sin(\alpha) * \cos(\beta);$$

$$y = Y - D * \sin(\alpha) * \sin(\beta);$$

**[0011]** In the formulas, x is the horizontal coordinate of the fire source in the two-dimensional navigation map; y is the vertical coordinate of the fire source in the two-dimensional navigation map; X is the horizontal coordinate of the fire source detection apparatus in the two-dimensional navigation map; Y is the vertical coordinate of the fire source detection apparatus in the two-dimensional navigation map; D is the distance from the camera to the fire source; $\alpha$ is the pitch angle; $\beta$ is the yaw angle.

**[0012]** It can be seen that the fire source position can be conveniently determined based on the distance, the pitch angle of the camera and the yaw angle of the camera in embodiments of the present invention. The calculation process is simple, and the fire source can be quickly located.

**[0013]** In one embodiment, the server is configured to determine a fire scene range in the two-dimensional navigation map based on the fire scene picture and determine the fire extinguishing position based on the fire scene range, a maximum fire extinguishing distance of the fire-fighting robot and the fire source position, wherein the fire extinguishing position is not in the fire scene range and the distance between the fire extinguishing position and the fire source position is no greater than the maximum fire extinguishing distance of the fire-fighting robot.

**[0014]** Therefore, the fire scene range in the two-dimensional navigation map can be determined based on the fire scene picture, and a safe and effective fire extinguishing distance can be determined based on the fire scene range and the maximum fire extinguishing distance of the fire-fighting robot in embodiments of the present invention. Not only the fire extinguishing effect is guaranteed, but also the safety of the fire-fighting robot is improved.

**[0015]** A server comprises:

a communication module, configured to receive detection parameters from the fire source detection apparatus;
a fire source position determination module, used to determine a fire source position based on the detection parameters;
a fire extinguishing position determination module, used to determine a fire extinguishing position of the fire-fighting robot based on the fire source position;
a sending module, used to send a first robot control command containing the fire extinguishing position to the fire-fighting robot so that the fire-fighting robot moves to the fire extinguishing position based on the first robot control command and performs a fire extinguishing operation on the fire source;
the fire source detection apparatus is arranged in a fixed position in a monitored area to detect any fire source in the monitored area.

**[0016]** Therefore, embodiments of the present invention provide a server for fire extinguishing operations, reducing the cost and improving the fire extinguishing efficiency. In addition, the power loss of the fire-fighting robot is reduced, a time window in which a fire-fighting operation is unable to be performed is avoided, and the fire-fighting safety is improved.

**[0017]** In one embodiment, the fire source detection apparatus comprises an adjustable PTZ dome; a camera, arranged on the adjustable PTZ dome to detect any fire source; a ranging sensor, arranged on the adjustable PTZ dome or the camera to detect a distance from the camera to the fire source; a communication module, used to send the detection parameters, wherein the detection parameters include at least one of the following: the distance, a pitch angle of the camera, a yaw angle of the camera; a fire scene picture;

the fire source determination module is configured to receive a two-dimensional navigation map of the monitored area from the fire-fighting robot and determine the coordinates (x, y) of the fire source in the two-dimensional navigation map based on the distance, the pitch angle of the camera and the yaw angle of the camera, wherein:

$$x = X - D * \sin(\alpha) * \cos(\beta);$$

$$y = Y - D * \sin(\alpha) * \sin(\beta);$$

x is the horizontal coordinate of the fire source in the two-dimensional navigation map; y is the vertical coordinate of the fire source in the two-dimensional navigation map; X is the horizontal coordinate of the fire source detection apparatus in the two-dimensional navigation map; Y is the vertical coordinate of the fire source detection apparatus in the two-dimensional navigation map; D is the distance from the camera to the fire source; $\alpha$ is the pitch angle; $\beta$ is the yaw angle.

**[0018]** It can be seen that the server in embodiments of the present invention can conveniently determine the fire source position based on the distance, the pitch angle of the camera and the yaw angle of the camera. The calculation process is simple, and the fire source can be quickly located.

**[0019]** In one embodiment, the fire extinguishing position determination module is configured to determine a fire scene range in the two-dimensional navigation map based on the fire scene picture and determine the fire extinguishing position based on the fire scene range, a maximum fire extinguishing distance of the fire-fighting robot and the fire source position, wherein the fire extinguishing position is not in the fire scene range and the distance between the fire extinguishing position and the fire source position is no greater than the maximum fire extinguishing distance of the fire-fighting robot.

**[0020]** Therefore, the server in embodiments of the present invention can further determine the fire scene range in the two-dimensional navigation map based on the fire scene picture and determine a safe and effective fire extinguishing distance based on the fire scene range and the maximum fire extinguishing distance of the fire-fighting robot. Not only the fire extinguishing effect is guaranteed, but also the safety of the fire-fighting robot is improved.

**[0021]** A fire-fighting robot comprises:

a communication module, used to receive a first robot control command containing a fire extinguishing position of the fire-fighting robot from a server;
a moving module, used to move to the fire extinguishing position based on the first robot control command;
a fire extinguishing module, used to perform a fire extinguishing operation on the fire source;
the server determines a fire source position based on detection parameters provided by the fire source detection apparatus arranged in a fixed position in a monitored area to detect any fire source in the monitored area, and determines the fire extinguishing position based on the fire source position.

**[0022]** It can be seen that embodiments of the present invention provide a fire-fighting robot, reducing the cost and improving the fire extinguishing efficiency. In addition, the power loss of the fire-fighting robot is reduced, a time window in which a fire-fighting operation is unable to be performed is avoided, and the fire-fighting safety is improved.

**[0023]** In one embodiment,

the fire source detection apparatus comprises an adjustable PTZ dome; a camera, arranged on the adjustable PTZ dome to detect any fire source; a ranging sensor, arranged on the adjustable PTZ dome or the camera to detect a distance from the camera to the fire source; a communication module, used to send the detection parameters, wherein the detection parameters include at least one of the following: the distance, a pitch angle of the camera, a yaw angle of the camera; a fire scene picture;
the communication module is further used to send a two-dimensional navigation map of the monitored area determined in automatic navigation mode to the server so that the server determines the coordinates of the fire source in the two-dimensional navigation map based on the distance, the pitch angle of the camera and the yaw angle of the camera, wherein:

$$x = X - D * \sin(\alpha) * \cos(\beta);$$

$$y = Y - D * \sin(\alpha) * \sin(\beta);$$

**[0024]** In the formulas, x is the horizontal coordinate of the fire source in the two-dimensional navigation map; y is the vertical coordinate of the fire source in the two-dimensional navigation map; X is the horizontal coordinate of the fire source detection apparatus in the two-dimensional navigation map; Y is the vertical coordinate of the fire source detection apparatus in the two-dimensional navigation map; D is the distance from the camera to the fire source; $\alpha$ is the pitch angle; $\beta$ is the yaw angle.

**[0025]** It can be seen that the fire-fighting robot in embodiments of the present invention can provide a two-dimensional navigation map of a monitored area for the server so that the server can conveniently determine the fire source position. In addition, the fire-fighting robot in embodiments of the present invention does not need to move continuously, and thus, the power loss of the fire-fighting robot is reduced and the safety of the fire-fighting robot is improved.

**[0026]** A fire extinguishing method comprises:

enabling a fire source detection apparatus arranged in a fixed position in a monitored area to detect any fire source in the monitored area;
determining a fire source position based on the detection parameters provided by the fire source detection apparatus;
determining a fire extinguishing position of a fire-fighting robot based on the fire source position;
sending a first robot control command containing the fire extinguishing position so that the fire-fighting robot moves to the fire extinguishing position based on the first robot control command and performs a fire extinguishing operation on the fire source.

**[0027]** It can be seen that fixedly deployed fire-fighting cannons are not adopted in embodiments of the present invention any longer, and thus the cost is reduced, and the fire extinguishing efficiency is improved. In addition, the fire-fighting robot in embodiments of the present invention does not need to move continuously, and thus, the power loss of the fire-fighting robot is reduced, a time window in which a fire-fighting operation is unable to be performed is avoided, and the fire-fighting safety is improved.

**[0028]** In one embodiment, the fire source detection apparatus comprises an adjustable PTZ dome; a camera, arranged on the adjustable PTZ dome to detect any fire source; a ranging sensor, arranged on the adjustable PTZ dome or the camera to detect a distance from the camera to the fire source; a communication module, configured to send the detection parameters, wherein the detection parameters include at least one of the following: the distance, a pitch angle of the camera, a yaw angle of the camera; a fire scene picture; determining a fire source position based on the detection parameters provided by the fire source detection apparatus comprises:

receiving a two-dimensional navigation map of the monitored area from the fire-fighting robot;
determining the coordinates (x, y) of the fire source in the two-dimensional navigation map based on the distance, the pitch angle of the camera and the yaw angle of the camera, wherein:

$$x = X - D * \sin(\alpha) * \cos(\beta);$$

$$y = Y - D * \sin(\alpha) * \sin(\beta);$$

**[0029]** In the formulas, x is the horizontal coordinate of the fire source in the two-dimensional navigation map; y is the vertical coordinate of the fire source in the two-dimensional navigation map; X is the horizontal coordinate of the fire source detection apparatus in the two-dimensional navigation map; Y is the vertical coordinate of the fire source detection apparatus in the two-dimensional navigation map; D is the distance from the camera to the fire source; $\alpha$ is the pitch angle; $\beta$ is the yaw angle.

**[0030]** Therefore, the fire source position can be conveniently determined based on the distance, the pitch angle of the camera and the yaw angle of the camera in embodiments of the present invention. The calculation process is simple and the fire source can be quickly located.

**[0031]** In one embodiment, determining a fire extinguishing position of a fire-fighting robot based on the fire source position comprises:

determining a fire scene range in the two-dimensional navigation map based on the fire scene picture;
determining the fire extinguishing position based on the fire scene range, a maximum fire extinguishing distance of the fire-fighting robot and the fire source position, wherein the fire extinguishing position is not in the fire scene range and the distance between the fire extinguishing position and the fire source position is no greater than the maximum fire extinguishing distance of the fire-fighting robot.

**[0032]** It can be seen that the fire scene range in the two-dimensional navigation map can be determined based on the fire scene picture, and a safe and effective fire extinguishing distance can be determined based on the fire scene range and the maximum fire extinguishing distance of the fire-fighting robot in embodiments of the present invention.

Not only the fire extinguishing effect is guaranteed, but also the safety of the fire-fighting robot is improved.

**[0033]** In one embodiment, the fire-fighting robot moving to the fire extinguishing position based on the first robot control command comprises: the fire-fighting robot in charging mode moving from a charging position to the fire extinguishing position based on the first robot control command; the method further comprises:

after the fire-fighting robot performing a fire extinguishing operation, sending a second robot control command instructing the fire-fighting robot to move to the charging position so that the fire-fighting robot moves to the charging position based on the second robot control command and enters charging mode.

**[0034]** Therefore, the fire-fighting robot in embodiments of the present invention does not need to move continuously and is located in the charging position for a long time, and thus, the power loss of the fire-fighting robot is reduced, a time window in which a fire-fighting operation is unable to be performed is avoided, and the fire-fighting safety is improved.

**[0035]** A sever comprises a processor, a memory and a computer program stored in the memory and able to run on the processor, and the computer program implements the above-mentioned fire extinguishing method when executed by the processor. Therefore, embodiments of the present invention further provide a server which comprises a computer program implementing the above-mentioned fire extinguishing method and has the memory-processor architecture.

**[0036]** A computer-readable storage medium is provided, a computer program is stored in the computer-readable storage medium and the computer program implements the above-mentioned fire extinguishing method when executed by a processor.

**[0037]** It can be seen that embodiments of the present invention further provide a computer-readable storage medium which contains a computer program implementing the above-mentioned fire extinguishing method.

## Brief Description of the Drawings

**[0038]**

Fig. 1 is a block diagram of the structure of the fire extinguishing system in embodiments of the present invention.

Fig. 2 is an exemplary block diagram of the structure of the fire extinguishing system in embodiments of the present invention.

Fig. 3 is a schematic diagram of the calculations of the fire source position and the fire extinguishing position in embodiments of the present invention.

Fig. 4 is a flowchart of the fire extinguishing method in embodiments of the present invention.

Fig. 5 is an exemplary flowchart of the fire extinguishing method in embodiments of the present invention.

Fig. 6 is an exemplary block diagram of the structure of the server having the memory-processor architecture.

Description of reference numerals in the drawings:

| | |
|---|---|
| 10 | Fire extinguishing system |
| 20 | Fire source detection apparatus |
| 30 | Server |
| 40 | Fire-fighting robot |
| 21 | Camera |
| 22 | Ranging sensor |
| 23 | Adjustable PTZ dome |
| 24 | Communication module |
| 31 | Communication module |
| 32 | Fire source position determination module |
| 33 | Fire extinguishing position determination module |
| 34 | Sending module |
| 41 | Communication module |
| 42 | Moving module |
| 43 | Fire extinguishing module |

(continued)

| | |
|---|---|
| 44 | Charging position |
| 45 | Safe circle |
| 400 | Fire extinguishing method |
| 401-404 | Steps |
| 500-511 | Steps |
| 600 | Server |
| 601 | Processor |
| 602 | Memory |

## Specific Embodiments

**[0039]** To make clearer the technical solution and advantages of the present invention, the present invention is further described in detail below in combination with the drawings and embodiments. It should be understood that the specific embodiments described here are used only to explain the present invention, but not to restrict the scope of protection of the present invention.

**[0040]** For the purpose of simplicity and intuitiveness of the description, a plurality of representative embodiments are given below to describe the solution of the present invention. A large amount of details in the embodiments are only used to help to understand the solution of the present invention. Obviously, the technical solution of the present invention is not limited to these details when implemented, however. To avoid unnecessarily confusing the solution of the present invention, some embodiments are not described in detail, and only their frameworks are given. Below, the term "comprise" refers to "include but are not limited to" and the term "according to..." refers to "at least according to..., but not limited to only according to...". In view of the linguistic habits of Chinese, the number of a component hereinafter can be one or more or can be understood as at least one, unless otherwise specified.

**[0041]** A robot is a mechanical device that can automatically perform tasks. It not only can accept human commands, but also run pre-compiled programs. In addition, it can act according to a guideline prepared by use of artificial intelligence technology. As a type of robots, fire-fighting robots increasingly play a decisive role in fire extinguishing and emergency rescues. Fire-fighting robots can take the place of firefighters to perform fire extinguishing tasks in dangerous disaster and accident sites where there are flammables and explosives, poison or heavy smoke or there is lack of oxygen. Embodiments of the present invention provide a fire extinguishing system that controls a fire-fighting robot to perform a fire extinguishing task.

**[0042]** Fig. 1 is a block diagram of a structure of a fire extinguishing system in an embodiment of the present invention.

**[0043]** As shown in Fig. 1, the fire extinguishing system 10 comprises:

a fire source detection apparatus 20, arranged in a fixed position in a monitored area to detect any fire source in the monitored area;

a server 30, used to determine a fire source position based on detection parameters provided by the fire source detection apparatus 20, determine the fire extinguishing position of a fire-fighting robot 40 based on the fire source position, and send a first robot control command containing the fire extinguishing position;

a fire-fighting robot 40, used to move to the fire extinguishing position based on the first robot control command and perform a fire extinguishing operation on the fire source.

**[0044]** In one embodiment, the fire-fighting robot 40 has an automatic navigation module (not shown in Fig. 1). At the stage of parameter settings of the fire extinguishing system 10, the automatic navigation module of the fire-fighting robot 40 realizes automatic navigation of the fire-fighting robot 40 in a monitored area (for example, garage, factory building, warehouse, etc.) and draws a two-dimensional navigation map of the monitored area. The fire-fighting robot 40 sends the two-dimensional navigation map to the server 30 through a wired interface or wireless interface between the fire-fighting robot and the server 30. Alternatively, the server 30 may acquire the two-dimensional map of the monitored area from other sources (for example, a special navigation map server). For example, the automatic navigation module may be implemented as a visual SLAM module. Visual SLAM is a computer vision-based technology. The principle of the visual SLAM module is as follows: A visual camera is used to take pictures of the ambient environment, and then the position and direction of the ambient environment are calculated, that is, a map is constructed for an unknown environment. Thus, automatic navigation of the fire-fighting robot is realized.

**[0045]** A typical example of the automatic navigation module is exemplarily described above. Those skilled in the art may realize that the description is only exemplary but is not used to limit the scope of protection of the embodiments of the present invention.

**[0046]** The fire source detection apparatus 20 arranged in a fixed position (for example, on a high wall or column) in the monitored area continuously detects any fire source in the monitored area.

**[0047]** Preferably, the fire source detection apparatus 20 may be implemented as a camera (for example, an infrared camera or infrared thermal imager) comprising an adjustable PTZ dome and supporting the ranging function (for example, laser ranging, ultrasonic ranging, etc.). Through the adjustable PTZ dome, the camera can sweep the whole monitored area. The camera monitors the temperature in the monitored area to determine whether there exists a fire source. When there exists a fire source, the fire source detection apparatus 20 determines the distance between the fire source detection apparatus and the fire source. Since the camera determines a fire by detecting the temperature, the camera can further detect a hidden fire in the monitored area. Usually, the maximum detection ranges of both the camera and the ranging function exceed 300 meters. Therefore, a large monitored area can be covered.

**[0048]** The server 30 may be arranged in the monitored area or around the monitored area or on a cloud. The server 30 communicates with the fire source detection apparatus 20 and the fire-fighting robot 40 through wired interfaces or wireless interfaces.

**[0049]** For example, the wired interfaces include at least one of the following: a universal serial bus (USB) interface, a controller LAN interface, a serial interface, etc., and the wireless interfaces include at least one of the following: an infrared interface, a near field communication interface, a Bluetooth interface, a Zigbee interface, a wireless broadband interface, a 3-G mobile communication interface, a 4-G mobile communication, a 5-G mobile communication interface, etc. Typical instances of wired interfaces and wireless interfaces are exemplarily described above. Those skilled in the art can know that the description is only exemplary but is not used to limit the scope of protection of the embodiments of the present invention.

**[0050]** The server 30 controls the PTZ dome of the fire source detection apparatus 20 in such a way that the camera of the fire detection apparatus 20 regularly sweeps the whole monitored area. When the fire source detection apparatus 20 detects a fire, the server 30 reads the pitch angle and the yaw angle of the fire source detection apparatus 20 and the distance between the fire source detection apparatus and the fire source and calculates the coordinates of the fire source in the two-dimensional navigation map. In addition, comprehensively considering the safety and the fire extinguishing efficiency of the fire-fighting robot 40, the server calculates the fire extinguishing position of the fire-fighting robot 40 based on the coordinates of the fire source and sends a first robot control command containing the fire extinguishing position to the fire-fighting robot.

**[0051]** In usual cases, the fire-fighting robot 40 is charged in the charging position and is in a standby state, waiting for a control command from the server 30. After receiving a first robot control command from the server 30, the fire-fighting robot 40 moves to the fire extinguishing position and put out the fire. After putting the fire out, the fire-fighting robot 40 returns to the charging position to be charged again and goes into a standby state.

**[0052]** For example, the fire-fighting robot 40 comprises a mobile platform; a liquid storage tank that is placed on the mobile platform and is used to store a fire-fighting medium; a pallet that is placed on the mobile platform and has N degrees of freedom, wherein N is a positive integer greater than or equal to 2; a nozzle that is fixed on the pallet and is used to spray out the fire-fighting medium in the liquid storage tank to put out a fire.

**[0053]** A typical structure of the fire-fighting robot 40 is exemplarily described above. Those skilled in the art can know that the description is only exemplary but is not used to limit the scope of protection of the embodiments of the present invention.

**[0054]** Based on the description above, Fig. 2 is an exemplary block diagram of the structure of a fire extinguishing system according to an embodiment of the present invention.

**[0055]** The fire source detection apparatus 20 is arranged in a fixed position in a monitored area to detect any fire source in the monitored area.

**[0056]** Specifically, the fire source detection apparatus 20 comprises:

(1.1) an adjustable PTZ dome 23 that can move left and right/up and down, for example;
(1.2) a camera 21 (for example, a thermal infrared imaging camera) that is arranged on the adjustable PTZ dome 23 to detect any fire source;
(1.3) a ranging sensor 22 (for example, a laser ranging sensor) that is arranged on the adjustable PTZ dome 23 or the camera 21 to detect the distance between the fire source detection apparatus and the fire source;
(1.4) a communication module 24 that is used to send detection parameters to the server 30 when the camera 21 detects a fire source, wherein the detection parameters include at least one of the following: the distance between the fire source detection apparatus and the fire source detected by the ranging sensor 22; a pitch angle of the camera 21; a yaw angle of the camera 21; a fire scene picture taken by the camera 21. The server 30 may be arranged in the monitored area or around the monitored area or on a cloud.

**[0057]** Specifically, the server 30 comprises:

(2.1) a communication module 31, used to receive detection parameters from the communication module 24 of the fire source detection apparatus 20;
(2.2) a fire source position determination module 32, used to determine a fire source position based on the detection parameters;
(2.3) a fire extinguishing position determination module 33, used to determine a fire extinguishing position of a fire-fighting robot 40 based on the fire source position;
(2.4) a sending module 34, used to send a first robot control command containing the fire extinguishing position to the fire-fighting robot 40 so that the fire-fighting robot 40 moves to the fire extinguishing position based on the first robot control command and performs a fire extinguishing operation for the fire source.

**[0058]** The fire-fighting robot 40 may be arranged in the monitored area or around the monitored area. Preferably, the fire-fighting robot 40 is arranged in the charging position. Specifically, the fire-fighting robot 40 comprises:

(3.1) a communication module 41, used to receive a first robot control command containing a fire extinguishing position of the fire-fighting robot 40 from the server 30;
(3.2) a moving module 42, used to move to the fire extinguishing position based on the first robot control command;
(3.3) a fire extinguishing module 43, used to perform a fire extinguishing operation on the fire source.

**[0059]** In embodiments of the present invention, the parameter setting process of the fire extinguishing system comprises: (a): The fire-fighting robot 40 uses the automatic navigation function to sweep a whole monitored area to draw a two-dimensional navigation map of the monitored area. (b): The coordinates of the camera 21 are recorded in the two-dimensional navigation map.(c): The maximum fire extinguishing distance (namely, maximum range) of the fire-fighting robot 40 is recorded. Then, the above-mentioned parameters are input into the server 30.

**[0060]** In one embodiment, an automatic navigation module is embedded into the moving module 42 of the fire-fighting robot 40. By use of the automatic navigation module, the automatic navigation of the fire-fighting robot 40 in the monitored area is realized and a two-dimensional navigation map of the monitored area is drawn. The communication module 41 of the fire-fighting robot 40 sends the two-dimensional navigation map to the communication module 31 of the server 30.

**[0061]** The server 30 controls the PTZ dome 23 of the fire source detection apparatus 20 in such a way that the camera 21 of the fire detection apparatus 20 regularly sweeps the whole monitored area. When the camera 21 detects a fire, the ranging sensor 22 detects the distance between the fire source detection apparatus and the fire source. In addition, the communication module 31 of the server 30 reads the pitch angle and the yaw angle of the camera 21 at the time when the camera 21 detects the fire and the distance detected by the ranging sensor 22, and the fire source position determination module 32 of the server 30 calculates the coordinates of the fire source in the two-dimensional navigation map. Furthermore, comprehensively considering the safety and the fire extinguishing efficiency of the fire-fighting robot 40, the fire extinguishing position determination module 33 of the server 30 calculates the fire extinguishing position of the fire-fighting robot 40 and sends a first robot control command containing the fire extinguishing position to the communication module 41 of the fire-fighting robot 40.

**[0062]** In one embodiment, the fire source determination module 32 is configured to receive a two-dimensional navigation map of the monitored area from the fire-fighting robot 40 and determine the coordinates (x, y) of the fire source in the two-dimensional navigation map based on the distance, the pitch angle of the camera 21 and the yaw angle of the camera 21, wherein:

$$x = X - D * \sin(\alpha) * \cos(\beta);$$

$$y = Y - D * \sin(\alpha) * \sin(\beta);$$

**[0063]** In the formulas, x is the horizontal coordinate of the fire source in the two-dimensional navigation map; y is the vertical coordinate of the fire source in the two-dimensional navigation map; X is the horizontal coordinate of the fire source detection apparatus 20 in the two-dimensional navigation map; Y is the vertical coordinate of the fire source detection apparatus 20 in the two-dimensional navigation map; D is the distance between the camera 21 and the fire source; $\alpha$ is the pitch angle of the camera 21; $\beta$ is the yaw angle of the camera.

**[0064]** In one embodiment, when the camera 21 of the fire source detection apparatus 20 detects an open fire, the camera 21 takes a picture of the fire scene. In addition, the communication module 24 of the fire source detection apparatus 20 sends the fire scene picture to the communication module 31 of the server 30. The fire extinguishing position determination module 33 of the server 30 is used to determine a fire scene range in the two-dimensional navigation map based on the fire scene picture and determine the fire extinguishing position based on the fire scene range, a maximum fire extinguishing distance of the fire-fighting robot 40 and the fire source position, wherein the fire extinguishing position is not in the fire scene range and the distance between the fire extinguishing position and the fire source position is no greater than the maximum fire extinguishing distance of the fire-fighting robot 40.

**[0065]** It can be seen that when an open fire is detected, the fire extinguishing position determined in embodiments of the present invention is not in the fire scene range, and thus the safety of the fire-fighting robot 40 is guaranteed. In addition, the distance between the fire extinguishing position and the fire source position is no greater than the maximum fire extinguishing distance of the fire-fighting robot 40, and thus the fire-fighting robot 40 can directly perform a fire extinguishing operation on the fire source.

**[0066]** In one embodiment, when the camera 21 of the fire source detection apparatus 20 fails to detect an open fire, preferably, the camera 21 takes no picture. At this time, the fire extinguishing position determination module 33 of the server 30 is used to determine a fire extinguishing position based on the maximum fire extinguishing distance of the fire-fighting robot 40 and the fire source position, wherein the fire extinguishing position and the fire source position are close enough (for example, the distance between the fire extinguishing position and the fire source position is less than or equal to a preset value, and the preset value is less than the maximum fire extinguishing distance).

**[0067]** It can be seen that when a hidden fire is detected, the fire extinguishing position and the fire source positions determined in embodiments of the present invention are close enough, thus ensuring that the fire-fighting robot 40 can high efficiently and directly put out the fire.

**[0068]** Fig. 3 is a schematic diagram of the calculations of a fire source position and a fire extinguishing position in embodiments of the present invention.

**[0069]** The major functions of the server 30 include:

(1) Calculating the coordinates of a fire source

One major function of the server 30 is to calculate the coordinates of a fire source in the two-dimensional navigation map determined by the automatic navigation module of the fire-fighting robot 40. The PTZ dome of the fire source detection apparatus 20 provides the server 30 with the pitch angle and the yaw angle of the camera 21, which are supposed to be $\alpha$ and $\beta$, at the time when the camera 21 of the fire source detection apparatus 20 detects a fire source. The ranging sensor of the fire source detection apparatus 20 provides the server 30 with the distance between the camera and the fire source, which is supposed to be D. At the stage of system settings, the server 30 has already obtained the coordinates (X, Y) of the camera in the two-dimensional navigation map.

**[0070]** The server 30 determines the coordinates (X,Y) of the fire source in the two-dimensional navigation map, wherein:

$$X = X - \Delta x = X - d * \cos(\beta) = X - D * \sin(\alpha) * \cos(\beta);$$

$$Y = Y - \Delta y = Y - d * \sin(\beta) = Y - D * \sin(\alpha) * \sin(\beta);$$

**[0071]** In the formulas, x is the horizontal coordinate of the fire source in the two-dimensional navigation map; y is the vertical coordinate of the fire source in the two-dimensional navigation map; X is the horizontal coordinate of the fire source detection apparatus in the two-dimensional navigation map; Y is the vertical coordinate of the fire source detection apparatus in the two-dimensional navigation map; D is the distance determined by the ranging sensor from the camera to the fire source; $\alpha$ is the pitch angle of the camera; $\beta$ is the yaw angle of the camera; d is the distance between the coordinate point (X, Y) and the coordinate point (x, y) in the two-dimensional navigation map. $\Delta x$ is the difference between X and x; $\Delta y$ is the difference between Y and y.

(2) Calculating the safe circle of the fire-fighting robot 40

**[0072]** The server 30 can calculate the safe circle 45 of the fire-fighting robot 40 according to the maximum range of the fire-fighting robot and the fire scene picture acquired from the camera. The fire extinguishing position is required to be located beyond the safe circle 45, and thus the safety of the fire-fighting robot is ensured. For example, the safe circle 45 may be implemented as an outline of the fire scene range or a circle covering the fire scene range determined based on the fire scene picture. The fire extinguishing position is not located in the safe circle to ensure the safety of the fire-fighting robot, and in addition, the distance between the fire extinguishing position and the fire source position is no greater than the maximum fire extinguishing distance of the fire-fighting robot 40 to ensure that the fire is effectively extinguished.

**[0073]** The fire-fighting robot 40 is usually charged in the charging position and is in a standby state, waiting for a control command from the server 30. After the fire-fighting robot 40 receives a first robot control command from the server 30, the fire-fighting robot 40 moves to the fire extinguishing position and put out the fire. After putting the fire out, the fire-fighting robot 40 returns to the charging position 44 to be charged again and goes into a standby state.

**[0074]** Typical examples of calculating a fire source position and a fire extinguishing position in embodiments of the present invention are described below.

**[0075]** Supposing that the coordinate point of the camera in the two-dimensional navigation map is (100, 200), the maximum range of the fire-fighting robot is supposed to be 40 meters, the pitch angle $\alpha$ of the camera is 30° and the yaw angle $\beta$ is 60° at the time when the camera reports a fire alarm, and the distance D that the ranging sensor reports to the server 30 is 100 meters,

**[0076]** Then, the server 30 can calculate the coordinates of the fire source:

$$X = 100 - 100 * \sin(30°) * \cos(60°) = 75;$$

$$Y = 200 - 100 * \sin(30°) * \sin(60°) = 156.7;$$

**[0077]** Therefore, the coordinates of the fire source are (75, 156.7). In addition, the radius of the safe circle calculated by the server 30 based on the fire scene range is 20 meters and such a radius can ensure that the fire-fighting robot is safe and can put out the fire as much as possible. The optimal fire extinguishing position given by the server is (75, 176.7). Then, the server 30 sends a fire extinguishing instruction containing the optimal position (75, 176.7) to the fire-fighting robot 40. After receiving the request, the fire-fighting robot 40 moves to the coordinate point (75, 176.7) to start putting out the fire. After putting out the fire, the fire-fighting robot 40 sends a response to the server 30, and then the fire-fighting robot 40 returns to the charging area. The server 30 goes into a loop again.

**[0078]** Based on the description above, embodiments of the present invention further provide a fire extinguishing method.

**[0079]** Fig. 4 is a flowchart of the fire extinguishing method of embodiments of the present invention.

**[0080]** As shown in Fig. 4, the method comprises:

Step 401: enabling a fire source detection apparatus arranged in a fixed position in a monitored area to detect any fire source in the monitored area.

Step 402: determining a fire source position based on the detection parameters provided by the fire source detection apparatus.

Step 403: determining a fire extinguishing position of a fire-fighting robot based on the fire source position.

Step 404: sending a first robot control command containing the fire extinguishing position so that the fire-fighting robot moves to the fire extinguishing position based on the first robot control command and performs a fire extinguishing operation on the fire source.

**[0081]** In one embodiment, the fire source detection apparatus comprises an adjustable PTZ dome; a camera, arranged on the adjustable PTZ dome to detect a fire source; a ranging sensor, arranged on the adjustable PTZ dome or the camera to detect a distance from the camera to the fire source; a communication module, used to send the detection parameters, wherein the detection parameters include at least one of the following: the distance, a pitch angle of the camera, a yaw angle of the camera; a fire scene picture; determining a fire source position based on the detection parameters provided by the fire source detection apparatus in Step 402 comprises: receiving a two-dimensional navigation map of the monitored area from the fire-fighting robot; determining the coordinates (x, y) of the fire source in the two-dimensional navigation map based on the distance, the pitch angle of the camera and the yaw angle of the camera; wherein $x = X - D * \sin(\alpha) * \cos(\beta)$; $y = Y - D * \sin(\alpha) * \sin(\beta)$, wherein x is the horizontal coordinate of the fire source in the two-dimensional navigation map; y is the vertical coordinate of the fire source in the two-dimensional navigation map; X is the horizontal coordinate of the fire source detection apparatus in the two-dimensional navigation map; Y is the vertical coordinate of the fire source detection apparatus in the two-dimensional navigation map; D is the distance from the camera to the fire source; $\alpha$ is the pitch angle; $\beta$ is the yaw angle.

**[0082]** In one embodiment, determining a fire extinguishing position of a fire-fighting robot based on the fire source position in Step 403 comprises:

determining a fire scene range in the two-dimensional navigation map based on the fire scene picture and determining the fire extinguishing position based on the fire scene range, a maximum fire extinguishing distance of the fire-fighting robot and the fire source position, wherein the fire extinguishing position is not in the fire scene range and the distance between the fire extinguishing position and the fire source position is no greater than the maximum fire extinguishing distance of the fire-fighting robot.

**[0083]** Based on the system architecture in Fig. 1 and the flowchart of the method in Fig. 4, Fig. 5 is an exemplary flowchart of the fire extinguishing method according to embodiments of the present invention. By default, the fire-fighting robot 40 is located in the charging area, waiting for a request from the server 30. The server 30 controls the PTZ dome in such a way that the camera regularly sweeps the whole monitored area. If the server 30 acquires a fire alarm from the camera, then the server: (1) moves the PTZ dome to keep the fire source located at the center of an image in the camera; (2) reads the distance from the fire source to the laser; (3) reads the pitch angle and the yaw angle of the camera from the PTZ dome; (4) calculates the coordinate point of the fire source in the two-dimensional navigation map; (5) calculates the safe circle of the fire-fighting robot 40 and determines a fire extinguishing position that overlaps the safe circle or is located beyond the safe circle; (6) sends a fire extinguishing request containing the fire extinguishing position to the fire-fighting robot 40; (7) waits for a response from the fire-fighting robot 40; (8) goes into a loop again after receiving a response from the fire-fighting robot 40. After receiving a fire extinguishing request from the server 30, the fire-fighting robot 40 moves to the fire extinguishing position and puts out the fire. After putting out the fire, the fire-fighting robot 40 sends a completion response to the server 30 and returns to the charging area again.

**[0084]** Specifically, as shown in Fig. 5, the fire extinguishing method comprises:

Step 500: The fire-fighting robot 40 is on standby in the charging position and waits for a command from the server 30.

Step 501: The server 30 sends a PTZ dome control instruction to the fire source detection apparatus 20, wherein the PTZ dome control instruction is used to control the regular movement of the PTZ dome of the fire source detection apparatus 20.

Step 502: The PTZ dome of the fire source detection apparatus 20 executes the PTZ dome control instruction, and then the camera, arranged on the PTZ dome, of the fire source detection apparatus 20 regularly sweeps the whole monitored area.

Step 503: The camera of the fire source detection apparatus 20 discovers a fire source based on a temperature detection and sends an alarm message to the server 30.

Step 504: The server 30 sends a PTZ dome control instruction to the fire source detection apparatus 20, wherein the PTZ dome control instruction is used to move the PTZ dome to keep the fire source located at the center of the picture taken by the camera.

Step 505: The server reads the distance between the camera and the fire source, acquired by the ranging sensor arranged on the PTZ dome.

Step 506: The server 30 reads the pitch angle and the yaw angle of the camera from the PTZ dome.

Step 507: The server 30 calculates the coordinates of the fire source in the two-dimensional navigation map based on the distance between the camera and the fire source, the pitch angle and the yaw angle of the camera, and the coordinates of the fire source detection apparatus 20 in the two-dimensional navigation map.

Step 508: The server 30 calculates the safe circle of the fire-fighting robot 40, determines the fire extinguishing position overlapping the safe circle or located beyond the safe circle, and sends a move instruction containing the fire extinguishing position to the fire-fighting robot 40.

Step 509: The fire-fighting robot 40 moves to the fire extinguishing position and performs a fire extinguishing task.

Step 510: The server 30 starts the next loop and goes back to perform step 500.

**[0085]** Based on the description above, embodiments of the present invention further provide a server having the memory-processor architecture.

**[0086]** Fig. 6 is an exemplary block diagram of the structure of the server having the memory-processor architecture.

**[0087]** As shown in Fig. 6, the sever 600 comprises a processor 601, a memory 602 and a computer program that is stored in the memory 602 and is able to run on the processor 601, and the computer program implements the above-mentioned fire extinguishing method when executed by the processor 601.

**[0088]** The memory 602 may be specifically implemented as an electrically erasable programmable read-only memory (EEPROM), a flash memory, a programmable ready-only memory (PROM) or other storage media. The processor 601 may be implemented as one or more processors or one or more field programmable gate arrays (FPGAs), wherein one or more central processing unit cores are integrated in the FPGA. Specifically, the central processing unit or the central processing unit core may be implemented as a CPU or MCU or DSP.

**[0089]** In summary, fixedly deployed fire-fighting cannons are no longer adopted in embodiments of the present invention so that the cost is reduced and the fire extinguishing efficiency is improved. In addition, embodiments of the present invention reduce the power loss of the fire-fighting robot and improve the safety of the fire-fighting robot. Embodiments of the present invention can ensure that fire monitoring is not interrupted, the fire-fighting robot has a sufficient energy to put out a fire, and a safe area is provided for the fire-fighting robot.

**[0090]** It should be noted that not all the steps or modules in the above-mentioned processes and structural diagrams are required, and some steps or modules may be omitted, depending on the actual requirements. The execution sequence of the steps is not fixed and may be adjusted as required. The module division is a functional division for the convenience of description. In the practical implementation, the function of a module may be realized by a plurality of modules, and the functions of a plurality of modules may be realized by one module and these modules may be located in the same equipment or may be located in different equipment.

**[0091]** The hardware modules in different embodiments can be realized mechanically or electronically. For example, a hardware module may comprise specially designed permanent circuits or logic devices (for example, application-specific processors such as FPGA or ASIC) to complete specific operations. A hardware module may also comprise programmable logic devices or circuits (for example, general processors or other programmable processors) temporarily configured by software to perform specific operations. Whether a hardware module is realized mechanically or by use of a dedicated permanent circuit or a temporarily configured circuit (for example, configured by software) may depend on the considerations of the cost and the time.

**[0092]** The present invention further provides a machine-readable storage medium, in which instructions allowing a machine to execute the method described in the present application are stored. Specifically, a system or device equipped with a storage medium may be provided. Software program codes which may realize the functions of any of above-mentioned embodiments are stored in the storage medium, and the computer (or CPU or MPU) of the system or device may read and execute the program codes stored in the storage medium. In addition, through the commands based on the program codes, the operating system on the computer may complete a part of or all of actual operations. In addition, the program codes read out of the storage medium may be written into the memory in an expansion board in the computer or may be written into the memory in an expansion unit connected to the computer, and then the commands based on the program codes allow the CPU installed on the expansion board or expansion unit to execute a part or all of actual operations to realize the functions of any of the above-mentioned embodiments.

**[0093]** The storage medium used to provide program codes includes a floppy disk, hard disk, magneto-optical disk, optical disk (for example, CD-ROM, CD-R, CD-RW, DVD-ROM, DVD-RAM, DVD-RW and DVD+RW), magnetic tape, non-volatile memory card, and ROM. Alternatively, program codes can be downloaded from a server computer or cloud over a communication network.

**[0094]** In this document, "schematic" means "acting as an instance, example, or illustration", and any schematic illustration or embodiment described in this document should not be interpreted as a more preferred or advantageous technical solution. For the simplicity of the drawings, only the parts related to the present invention are shown for a schematic purpose and they do not represent the actual structure of a product. In addition, only one of the components which have the same structure or function is depicted or marked for a schematic purpose in some drawings so that the drawings are simplified to help with understanding. In this document, the term "one" does not mean that the number of related parts of the present invention is limited to "only one", and the term "one" does not mean that the situation that the number of related parts of the present invention is "greater than one" is excluded. In this document, the terms "above", "below", "front", "rear", "left", "right", "in" and "beyond" are only used to represent relative position relationships between related parts, but are not used to define the absolute positions of these related parts.

**[0095]** The embodiments described above are preferred embodiments of the present invention, but are not used to limit the protection scope of the present invention. Any modification, equivalent replacement, and improvement within the spirit and principle of the present invention should fall within the scope of protection of the present invention.

## Claims

1. A fire extinguishing system (10), **characterized in that** the fire extinguishing system comprises:

   a fire source detection apparatus (20), arranged in a fixed position in a monitored area to detect a fire source in the monitored area;
   a server (30), used to determine a fire source position based on detection parameters provided by the fire source detection apparatus (20), determine the fire extinguishing position of a fire-fighting robot (40) based on the fire source position, and send a first robot control command containing the fire extinguishing position;
   a fire-fighting robot (40), used to move to the fire extinguishing position based on the first robot control command and perform a fire extinguishing operation for the fire source.

2. The fire extinguishing system (10) as claimed in claim 1, **characterized in that**

   the fire source detection apparatus (20) comprises:

      an adjustable pan/tilt/zoom (PTZ) dome (23);
      a camera (21), arranged on the adjustable PTZ dome (23) to detect a fire source;
      a ranging sensor (22), arranged on the adjustable PTZ dome (23) or the camera (21) to detect a distance

from the camera to the fire source;

a communication module (24), used to send the detection parameters, wherein the detection parameters include at least one of the following:
the distance; a pitch angle of the camera (21); a yaw angle of the camera (21); a fire scene picture.

**3.** The fire extinguishing system (10) as claimed in claim 2, **characterized in that**
the server (30) is used to receive a two-dimensional navigation map of the monitored area from the fire-fighting robot (40) and determine the coordinates (x, y) of the fire source in the two-dimensional navigation map based on the distance, the pitch angle of the camera (21) and the yaw angle of the camera (21), wherein:

$$x = X - D * \sin(\alpha) * \cos(\beta);$$

$$y = Y - D * \sin(\alpha) * \sin(\beta);$$

x is the horizontal coordinate of the fire source in the two-dimensional navigation map; y is the vertical coordinate of the fire source in the two-dimensional navigation map; X is the horizontal coordinate of the fire source detection apparatus (20) in the two-dimensional navigation map; Y is the vertical coordinate of the fire source detection apparatus (20) in the two-dimensional navigation map; D is the distance from the camera to the fire source; $\alpha$ is the pitch angle; $\beta$ is the yaw angle.

**4.** The fire extinguishing system (10) as claimed in claim 2 or 3, **characterized in that**
the server (30) is used to determine a fire scene range in the two-dimensional navigation map based on the fire scene picture and determine the fire extinguishing position based on the fire scene range, a maximum fire extinguishing distance of the fire-fighting robot (40) and the fire source position, wherein the fire extinguishing position is not in the fire scene range and the distance between the fire extinguishing position and the fire source position is no greater than the maximum fire extinguishing distance of the fire-fighting robot (40) .

**5.** A server (30), **characterized in that** the server comprises:

a communication module (31), used to receive detection parameters from the fire source detection apparatus (20);
a fire source position determination module (32), used to determine a fire source position based on the detection parameters;
a fire extinguishing position determination module (33), used to determine a fire extinguishing position of a fire-fighting robot (40) based on the fire source position;
a sending module (34), used to send a first robot control command containing the fire extinguishing position to the fire-fighting robot (40) so that the fire-fighting robot (40) moves to the fire extinguishing position based on the first robot control command and performs a fire extinguishing operation on the fire source;
the fire source detection apparatus (20) is arranged in a fixed position in a monitored area to detect a fire source in the monitored area.

**6.** The server (30) as claimed in claim 5, **characterized in that**

the fire source detection apparatus (20) comprises an adjustable PTZ dome (23); a camera (21), arranged on the adjustable PTZ dome (23) to detect a fire source; a ranging sensor (22), arranged on the adjustable PTZ dome (23) or the camera (21) to detect a distance from the camera to the fire source; a communication module (24), used to send the detection parameters, wherein the detection parameters include at least one of the following: the distance, a pitch angle of the camera (21), a yaw angle of the camera (21); a fire scene picture;
the fire source determination module (32) is used to receive a two-dimensional navigation map of the monitored area from the fire-fighting robot (40) and determine the coordinates (x, y) of the fire source in the two-dimensional navigation map based on the distance, the pitch angle of the camera (21) and the yaw angle of the camera (21), wherein:

$$x = X - D * \sin(\alpha) * \cos(\beta);$$

$$y = Y - D * \sin(\alpha) * \sin(\beta);$$

x is the horizontal coordinate of the fire source in the two-dimensional navigation map; y is the vertical coordinate of the fire source in the two-dimensional navigation map; X is the horizontal coordinate of the fire source detection apparatus (20) in the two-dimensional navigation map; Y is the vertical coordinate of the fire source detection apparatus (20) in the two-dimensional navigation map; D is the distance from the camera to the fire source; α is the pitch angle; β is the yaw angle.

**7.** The server (30) as claimed in claim 5 or 6, **characterized in that** the fire extinguishing position determination module (33) is used to determine a fire scene range in the two-dimensional navigation map based on the fire scene picture and determine the fire extinguishing position based on the fire scene range, a maximum fire extinguishing distance of the fire-fighting robot (40) and the fire source position, wherein the fire extinguishing position is not in the fire scene range and the distance between the fire extinguishing position and the fire source position is no greater than the maximum fire extinguishing distance of the fire-fighting robot (40).

**8.** A fire-fighting robot (40), **characterized in that** the fire-fighting robot comprises:

a communication module (41), used to receive a first robot control command containing a fire extinguishing position of the fire-fighting robot (40) from a server (30);
a moving module (42), used to move to the fire extinguishing position based on the first robot control command;
a fire extinguishing module (43), used to perform a fire extinguishing operation for the fire source;
the server (30) determines a fire source position based on detection parameters provided by the fire source detection apparatus (20) arranged in a fixed position in a monitored area to detect a fire source in the monitored area, and determines the fire extinguishing position based on the fire source position.

**9.** The fire-fighting robot (40) as claimed in claim 8, **characterized in that**

the fire source detection apparatus (20) comprises an adjustable PTZ dome (23); a camera (21), arranged on the adjustable PTZ dome (23) to detect a fire source; a ranging sensor (22), arranged on the adjustable PTZ dome (23) or the camera (21) to detect a distance from the camera to the fire source; a communication module (24), configured to send the detection parameters, wherein the detection parameters include at least one of the following: the distance, a pitch angle of the camera (21), a yaw angle of the camera (21); a fire scene picture;
the communication module (41) is further configured to send a two-dimensional navigation map of the monitored area determined in automatic navigation mode to the server (30) so that the server (30) determines the coordinates (x, y) of the fire source in the two-dimensional navigation map based on the distance, the pitch angle of the camera (21) and the yaw angle of the camera (21), wherein:

$$x = X - D * \sin(\alpha) * \cos(\beta);$$

$$y = Y - D * \sin(\alpha) * \sin(\beta);$$

x is the horizontal coordinate of the fire source in the two-dimensional navigation map; y is the vertical coordinate of the fire source in the two-dimensional navigation map; X is the horizontal coordinate of the fire source detection apparatus (20) in the two-dimensional navigation map; Y is the vertical coordinate of the fire source detection apparatus (20) in the two-dimensional navigation map; D is the distance from the camera to the fire source; α is the pitch angle; β is the yaw angle.

**10.** A fire extinguishing method (400), **characterized in that** the fire extinguishing method comprises:

enabling a fire source detection apparatus arranged in a fixed position in a monitored area to detect a fire source in the monitored area (401);
determining a fire source position based on the detection parameters provided by the fire source detection apparatus (402) ;
determining a fire extinguishing position of a fire-fighting robot based on the fire source position (403);

sending a first robot control command containing the fire extinguishing position so that the fire-fighting robot moves to the fire extinguishing position based on the first robot control command and performs a fire extinguishing operation for the fire source (404).

**11.** The fire extinguishing method (400) as claimed in claim 10, **characterized in that**

the fire source detection apparatus comprises an adjustable PTZ dome; a camera, arranged on the adjustable PTZ dome to detect a fire source; a ranging sensor, arranged on the adjustable PTZ dome or the camera to detect a distance from the camera to the fire source; a communication module, used to send the detection parameters, wherein the detection parameters include at least one of the following: the distance, a pitch angle of the camera, a yaw angle of the camera; a fire scene picture;
determining a fire source position based on the detection parameters provided by the fire source detection apparatus (402) comprises:

receiving a two-dimensional navigation map of the monitored area from the fire-fighting robot;
determining the coordinates (x, y) of the fire source in the two-dimensional navigation map based on the distance, the pitch angle of the camera and the yaw angle of the camera, wherein:

$$x = X - D * \sin(\alpha) * \cos(\beta);$$

$$y = Y - D * \sin(\alpha) * \sin(\beta);$$

x is the horizontal coordinate of the fire source in the two-dimensional navigation map; y is the vertical coordinate of the fire source in the two-dimensional navigation map; X is the horizontal coordinate of the fire source detection apparatus in the two-dimensional navigation map; Y is the vertical coordinate of the fire source detection apparatus in the two-dimensional navigation map; D is the distance from the camera to the fire source; $\alpha$ is the pitch angle; $\beta$ is the yaw angle.

**12.** The fire extinguishing method (400) as claimed in claim 11, **characterized in that**
determining a fire extinguishing position of a fire-fighting robot based on the fire source position (403) comprises:

determining a fire scene range in the two-dimensional navigation map based on the fire scene picture;
determining the fire extinguishing position based on the fire scene range, a maximum fire extinguishing distance of the fire-fighting robot and the fire source position, wherein the fire extinguishing position is not in the fire scene range and the distance between the fire extinguishing position and the fire source position is no greater than the maximum fire extinguishing distance of the fire-fighting robot.

**13.** The fire extinguishing method (400) as claimed in claim 10, **characterized in that**
the fire-fighting robot moving to the fire extinguishing position based on the first robot control command comprises: the fire-fighting robot in charging mode moving from a charging position to the fire extinguishing position based on the first robot control command; the method further comprises:
after the fire-fighting robot performing a fire extinguishing operation, sending a second robot control command instructing the fire-fighting robot to move to the charging position so that the fire-fighting robot moves to the charging position based on the second robot control command and enters charging mode.

**14.** A sever (600), **characterized in that** the server comprises a processor (601), a memory (602) and a computer program stored in the memory (602) and able to run on the processor (601), and the computer program implements the fire extinguishing method (400) as claimed in any of claims 10 to 13 when executed by the processor (601).

**15.** A computer-readable storage medium, **characterized in that** a computer program is stored in the computer-readable storage medium and the computer program implements the fire extinguishing method (400) as claimed in any of claims 10 to 13 when executed by a processor.

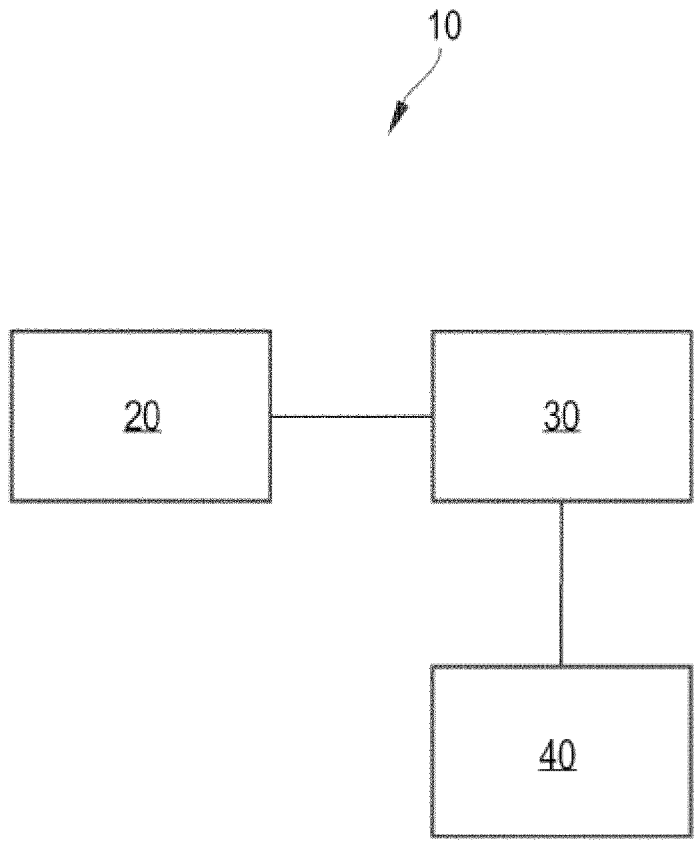


Fig. 1

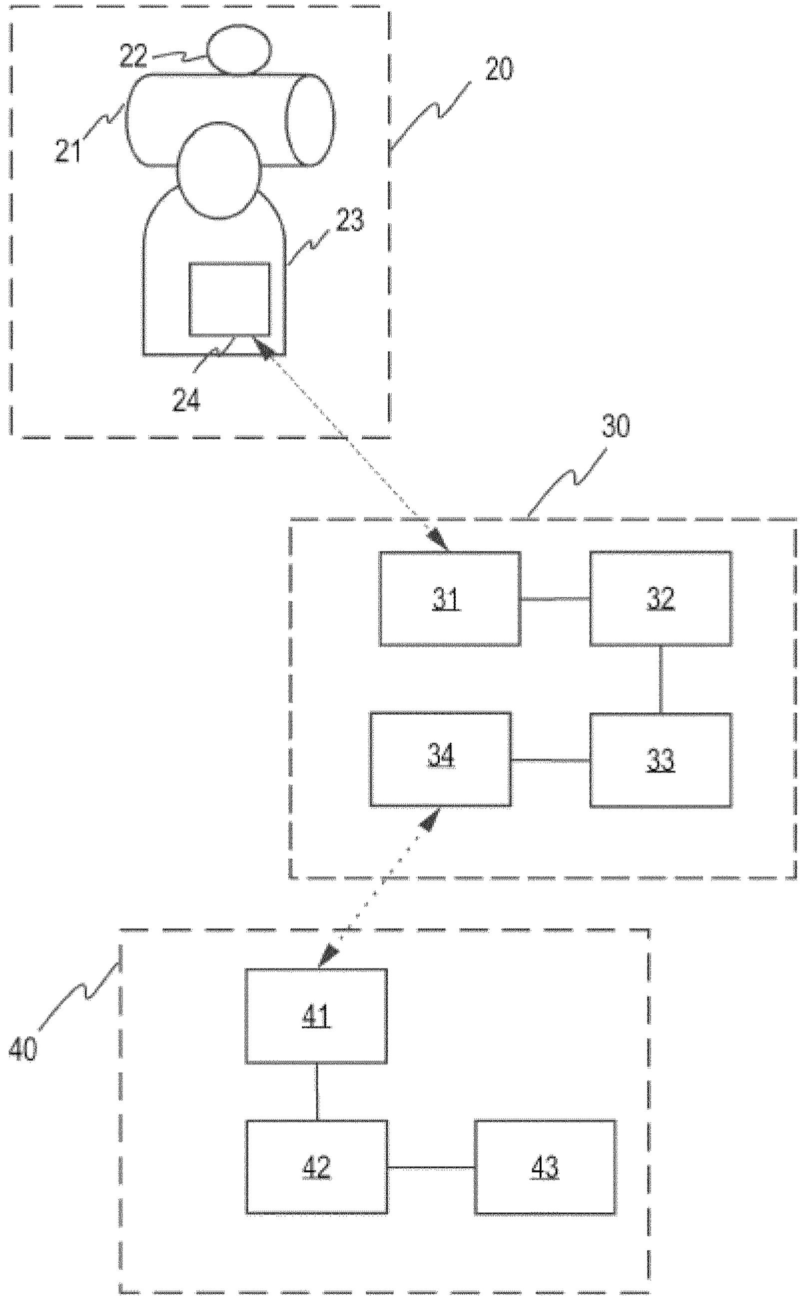


Fig. 2

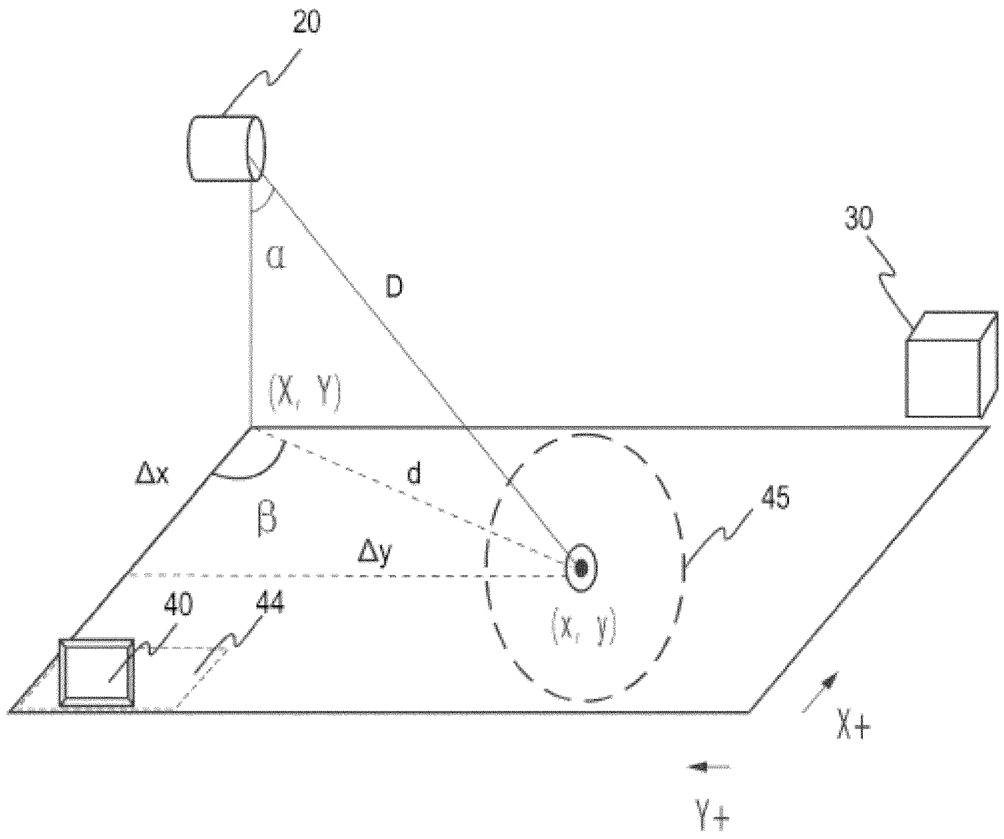


Fig. 3

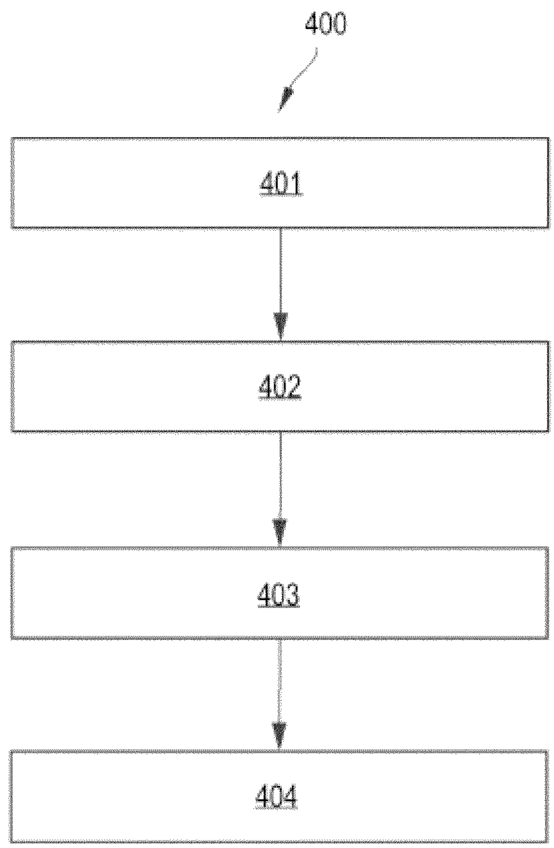


Fig. 4

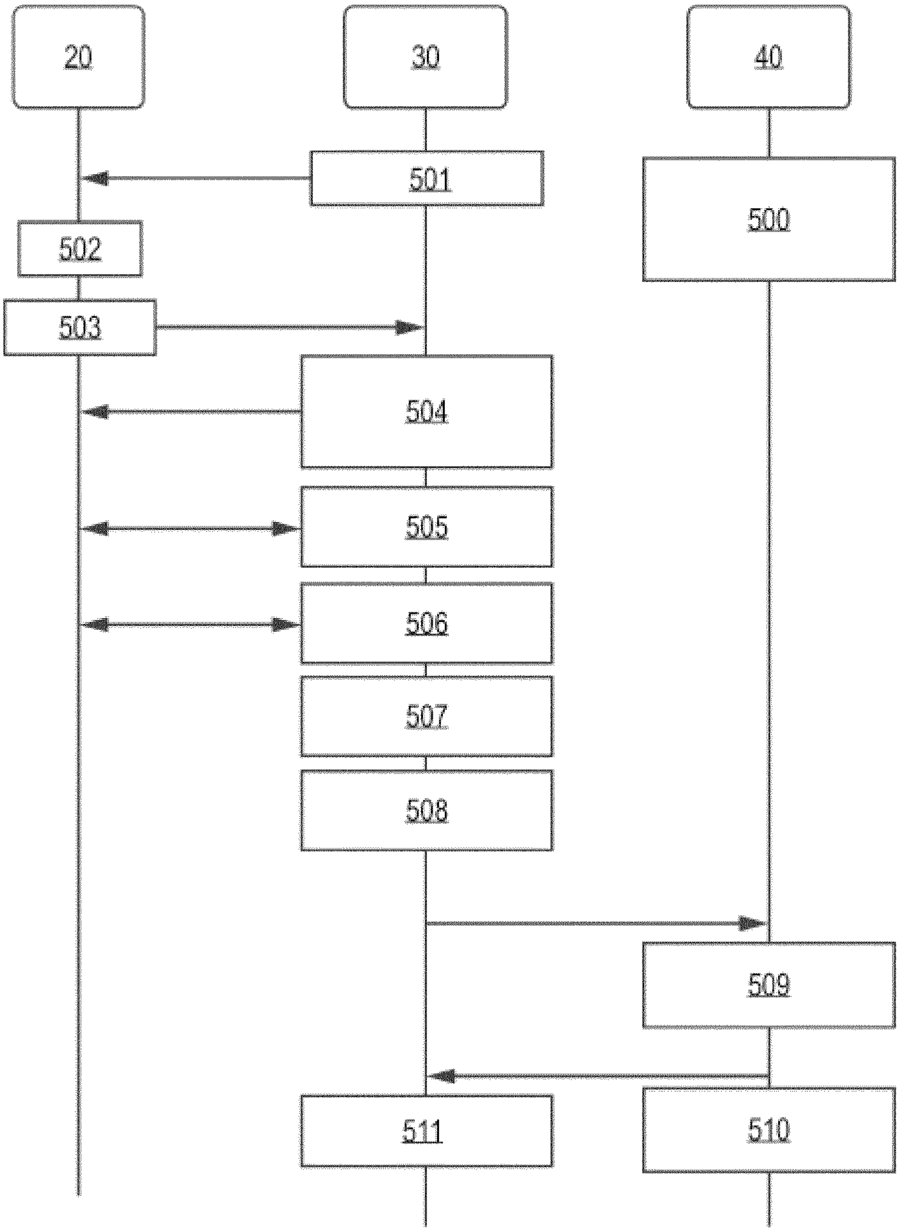


Fig. 5

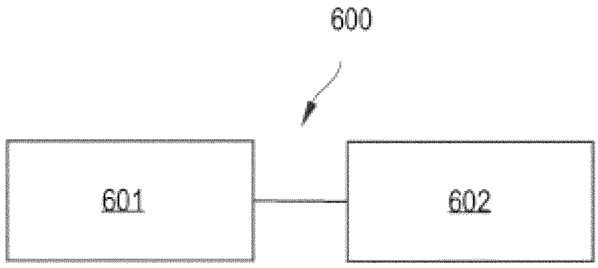


Fig. 6

## INTERNATIONAL SEARCH REPORT

International application No.
**PCT/CN2020/099332**

**A. CLASSIFICATION OF SUBJECT MATTER**

A62C 37/50(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)

A62C

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)

CNPAT, EPODOC, WPI, CNKI: 灭火, 消防, 机器人, 三角函数, FIRE+, ROBOT+, TRIANGLE+, TRIGONOMETRIC

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | CN 111111074 A (SHANDONG CANWELL COMMUNICATION TECHNOLOGY CO., LTD.) 08 May 2020 (2020-05-08) description, paragraphs 35-95, and figures 1-6 | 1, 2, 4, 5, 7, 8, 10, 13-15 |
| Y | CN 111111074 A (SHANDONG CANWELL COMMUNICATION TECHNOLOGY CO., LTD.) 08 May 2020 (2020-05-08) description, paragraphs 35-95, and figures 1-6 | 3-4, 6-7, 9, 11-12, 14-15 |
| Y | CN 105954718 A (QINGDAO KRUND ROBOT CO., LTD.) 21 September 2016 (2016-09-21) description, paragraphs 22-40, figure 1 | 3-4, 6-7, 9, 11-12, 14-15 |
| A | CN 210228955 U (SHANDONG GUOXING INTELLIGENT TECHNOLOGY CO., LTD. et al.) 03 April 2020 (2020-04-03) entire document | 1-15 |
| A | CN 109910010 A (GUANGDONG UNIVERSITY OF PETROCHEMICAL TECHNOLOGY) 21 June 2019 (2019-06-21) entire document | 1-15 |
| A | CN 109801358 A (NINGBO ELECTRIC POWER DESIGN INSTITUTE CO., LTD.) 24 May 2019 (2019-05-24) entire document | 1-15 |

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

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "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 |
|---|---|
| **09 March 2021** | **26 March 2021** |
| Name and mailing address of the ISA/CN<br>**China National Intellectual Property Administration (ISA/CN)**<br>**No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088**<br>**China** | Authorized officer |
| Facsimile No. **(86-10)62019451** | Telephone No. |

Form PCT/ISA/210 (second sheet) (January 2015)

**INTERNATIONAL SEARCH REPORT**

International application No.
**PCT/CN2020/099332**

| C. DOCUMENTS CONSIDERED TO BE RELEVANT | | |
|---|---|---|
| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
| A | CN 205182046 U (XI'AN UNIVERSITY OF SCIENCE AND TECHNOLOGY et al.) 27 April 2016 (2016-04-27)<br>entire document | 1-15 |
| A | CN 210228953 U (SHANDONG GUOXING INTELLIGENT TECHNOLOGY CO., LTD. et al.) 03 April 2020 (2020-04-03)<br>entire document | 1-15 |
| A | US 2013112440 A1 (KING SAUD UNIVERSITY et al.) 09 May 2013 (2013-05-09)<br>entire document | 1-15 |
| A | KR 20160139305 A (YANG, Dong Gook) 07 December 2016 (2016-12-07)<br>entire document | 1-15 |

Form PCT/ISA/210 (second sheet) (January 2015)

**INTERNATIONAL SEARCH REPORT**
**Information on patent family members**

International application No.
**PCT/CN2020/099332**

| Patent document cited in search report | Publication date (day/month/year) | Patent family member(s) | Publication date (day/month/year) |
|---|---|---|---|
| CN 111111074 A | 08 May 2020 | None | |
| CN 105954718 A | 21 September 2016 | None | |
| CN 210228955 U | 03 April 2020 | None | |
| CN 109910010 A | 21 June 2019 | None | |
| CN 109801358 A | 24 May 2019 | None | |
| CN 205182046 U | 27 April 2016 | None | |
| CN 210228953 U | 03 April 2020 | None | |
| US 2013112440 A1 | 09 May 2013 | US 8973671 B2 | 10 March 2015 |
| KR 20160139305 A | 07 December 2016 | None | |

Form PCT/ISA/210 (patent family annex) (January 2015)