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(71) Applicant: **Inventio AG**
6052 Hergiswil (CH)

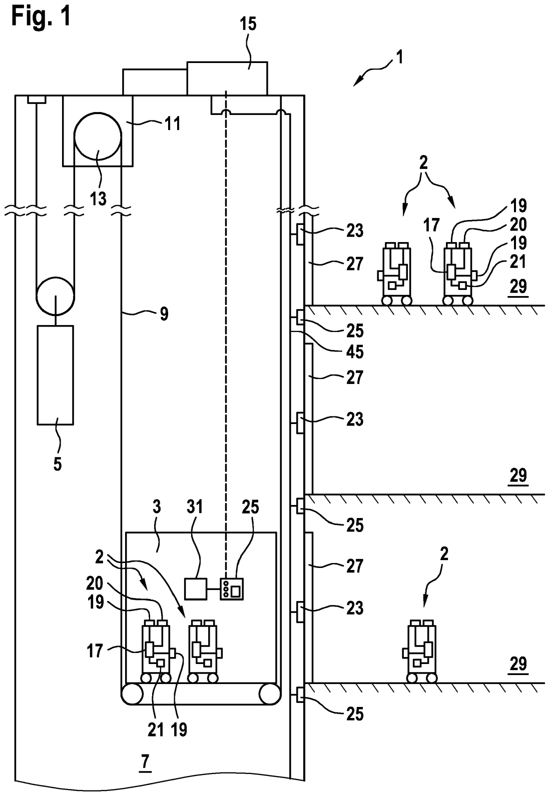
(72) Inventors:
- **ZAUGG, Gottfried**
Budd Lake, 07828 (US)
- **MORI, Erik**
West Orange, 07052 (US)

(54) **METHOD FOR CHECKING FUNCTIONS AND CONDITIONS OF AN ELEVATOR USING AUTONOMOUS MOBILE ROBOTS**

(57) A method for checking functions and conditions of an elevator (1) is proposed, the method comprising the following steps:
- providing at least one autonomous mobile robot (2), the robot being adapted to autonomously moving from a floor (29) of a building into a cabin (3) of the elevator (1) and vice versa;
- performing a checking procedure during which the cabin (3) of the elevator (1) is displaced multiple times between various floors (29) of the building and the at least one autonomous mobile robot (2) repeatedly enters and leaves the cabin (3) at various floors (29);
- monitoring the functions and conditions of the elevator (1) during the checking procedure.

Therein, the autonomous mobile robots (2) may emulate e.g. normal use of the elevator (1) by passengers including load changes in the cabin (3) induced by entering or leaving passengers. Thereby, the functions and conditions of the elevator (1) may be monitored under more realistic conditions and therefore the functions and conditions may be checked with higher reliability.

Fig. 1



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Description

[0001] The present invention relates to a method for checking functions and conditions of an elevator. Furthermore, the present invention relates to an autonomous mobile robot configured to perform such method, a computer program product for instructing such robot to perform such method and a computer-readable medium comprising such computer program product stored thereon.

[0002] Elevators serve for transporting passengers or items between different levels or floors within a building. Modem elevators may be adapted for providing a multiplicity of functions for enhancing a safety and/or increasing travelling comfort for passengers. Inter alia, such functions may include basic functions of the elevator and may for example be travelling functions for controlling a correct required displacement of an elevator cabin within an elevator shaft between intended levels or floors. Furthermore, such functions may include safety functions for increasing safety during operation and use of the elevator, such as correctly attenuating operation brakes of the elevators for decelerating the elevator cabin at intended positions without excessive jerks, supervising an entry to the elevator cabin using for example a light curtain in order to avoid passengers entering the cabin from being confronted with a closing cabin door, levelling functions for supervising and controlling cabin movement such that a cabin bottom is levelled with a floor bottom of an adjacent building floor as long as cabin doors are open such as to avoid steps between the cabin bottom and the floor bottom, etc. Furthermore, the elevator functions may include further functions such as a load detection function for detecting a current load of the elevator cabin, etc.

[0003] Additionally to the various functions to be intentionally provided and/or controlled in the elevator, various conditions may apply during elevator operation. For example, upon certain insufficiencies occurring during elevator operation, cabin movement may no longer be steady and smooth but jerking of the elevator cabin during its motions may occur, thereby generally annoying passengers. Furthermore, insufficiencies in bearings or guide rails may result in scratching and/or noise generation during displacements of the elevator cabin throughout the elevator shaft. Same may apply for motions of elevator doors.

[0004] Generally, functions and conditions of the elevator have to be checked at least after installation and before a first operation of the elevator. Furthermore, the functions and conditions are generally checked in certain time intervals during operation of the elevator such that deteriorations or even failures may be recognized and maintenance or countermeasures may be initiated.

[0005] Conventionally, for checking the functions and conditions of the elevator, a checking procedure is performed during which the elevator is controlled to perform specific operation functions. For example, during the checking procedure, the elevator cabin is specifically displaced to each of multiple floors within the building and/or elevator doors are opened at each of such floors. During such checking procedure, the functions and conditions of the elevator are monitored in order to obtain information about any malfunctions or failures.

[0006] However, it has been observed that by performing conventional checking procedures, some specific malfunctions or failures in the elevator were not detected with sufficient reliability. Furthermore, performing conventional checking procedures typically requires substantive efforts and work of trained maintenance staff, thereby incurring additional costs.

[0007] Accordingly, there may be a need for an improved method for checking functions and conditions of an elevator, such method overcoming at least some of the above-mentioned deficiencies. Particularly, there may be a need for a method for checking functions and conditions of the elevator which enables detecting malfunctions and/or failures with high reliability and/or at low efforts and/or low costs. Additionally, there may be a need for a device which is configured for performing such method, a computer program product configured for instructing such device for performing such method and for a computer-readable medium comprising such computer program product stored thereon.

[0008] Such needs may be met with the subject-matter of the independent claims. Advantageous embodiments are defined in the dependent claims as well as in the following specification.

[0009] According to a first aspect of the invention, a method for checking functions and conditions of an elevator is proposed. The method comprises the following steps, wherein method steps may be performed in the indicated order, in another order or simultaneously: (i) at least one autonomous mobile robot is provided, the robot being adapted to autonomously moving from a floor of a building into a cabin of the elevator and vice versa; (ii) a checking procedure is performed during which the cabin of the elevator is displaced multiple times between various floors of the building and the at least one robot repeatedly enters and leaves the cabin at various floors; and (iii) the functions and conditions of the elevator are monitored during the checking procedure.

[0010] A second aspect of the invention relates to an autonomous mobile robot, the robot being configured to perform a method according to an embodiment of the above first aspect of the invention.

[0011] A third aspect of the invention relates to a computer program product comprising instructions which, when executed in a programmable control of an autonomous mobile robot, instruct the robot to perform a method according to an embodiment of the above first aspect of the invention.

[0012] A fourth aspect of the invention relates to a computer-readable medium comprising a computer program product according to an embodiment of the above third aspect of the invention stored thereon.

[0013] Ideas underlying embodiments of the present invention may be interpreted as being based, inter alia and without restricting a scope of the invention, on the following observations and recognitions:

As briefly indicated in the introductory portion, it has been found that conventional checking procedures were not in all cases able to detect malfunctions or failures in an elevator with sufficient reliability. Particularly, it has been found that during such checking procedures, operation conditions in the elevator sometimes did not sufficiently correspond or emulate real operation conditions of the elevator during normal operation. Specifically, while during conventional checking procedures, an elevator cabin was for example displaced to various floors of the building and, optionally, cabin doors were opened and closed there, no passengers were entering and leaving from the elevator cabin during such conventional checking procedures.

[0014] It has been found that some functions and/or conditions in an elevator may only be checked or may be better checked in realistic operation conditions as they occur upon the elevator being used by passengers. For example, some functions and/or conditions may only be checked upon weight variations occurring within the elevator cabin as they occur upon passengers entering and leaving the elevator cabin. For example, a levelling function of the elevator keeping the elevator cabin with its bottom levelled to a neighbouring floor bottom may substantially be influenced by weight variations within the cabin. Similarly, effects of brakes attenuated for stopping the elevator cabin at intended positions within the elevator shaft are generally substantially influenced by weight variations within the cabin. Furthermore, specific functions of the elevator such as its light curtain at the elevator doors may only be checked upon being temporarily actuated, i.e. upon the light curtain being temporarily interrupted.

[0015] While it is assumed that simulating normal operation conditions during the checking procedure by instructing real human passengers to normally use the elevator would normally not be feasible, it has now been found that such normal operation conditions may be emulated using specifically configured autonomous mobile robots.

[0016] Such autonomous mobile robots (AMR) may, at least to a specific degree, may emulate motions and/or behaviour of passengers during normal operation of the elevator. Particularly, an autonomous mobile robot may be specifically configured to autonomously moving within floors of a building and from a floor into a cabin of the elevator, and vice versa, thereby emulating a passenger's motions upon using the elevator. Such motions of the autonomous mobile robot may, inter alia, induce weight variations in the elevator cabin thereby better enabling checking of functions and conditions which may be influenced by such weight variations. As a result, the specific use of autonomous mobile robots autonomously moving into and out of the elevator cabin during a checking procedure may enable detecting various malfunctions and/or failures and may thereby enable more reliably checking the functions and conditions of the elevator.

[0017] Herein, the term "autonomous mobile robot" (AMR), which is sometimes also referred to as "autonomous guided vehicle" (AGV), may be interpreted as referring to a device which, on the one hand is mobile, i.e. may actively move within an environment, and which, on the other hand, is autonomous, i.e. may control its motions within the environment without each and every motion being pre-programmed or guided by external means. Particularly, an AMR may perform behaviours or tasks with a high degree of autonomy, i.e. may adapt its actions to varying and sometimes unpredictable conditions. Therein, at least to a certain degree, the AMR may gain information about its environment and may move itself or at least parts of itself throughout its operation environment without human assistance. Particularly, situations that may be harmful for people, property or the AMR itself may be recognized by the AMR such that the AMR may adapt its actions such as to avoid such harms. Furthermore, the AMR may automatically operate for extended periods without human interactions or interventions.

[0018] In the checking procedure proposed herein, the autonomous mobility capabilities of one or more AMRs may be specifically adapted for emulating or simulating motions and/or behaviours of passengers during normal use of the elevator. Specifically, an AMR may wait in a floor of a building for a cabin of the elevator to arrive at this floor and open its doors. The AMR may then recognize the open access to the elevator cabin and may autonomously enter the cabin. After the cabin having moved to another floor and opened its doors there, the AMR may recognize the open exit and may leave the elevator cabin. The AMR may then wait for another mission. Such process may be repeated multiple times and/or may be executed by one or multiple AMRs.

[0019] According to an embodiment of the invention, the AMR may further be adapted to communicate with the elevator such as to actively transmit requests to the elevator for displacing the cabin to an intended floor, wherein, during the checking procedure, the at least one AMR repeatedly requests the cabin to come to a floor where the AMR is currently waiting, then the AMR enters the cabin and requests the cabin to be displaced to another floor, and then the AMR exits the cabin at the other floor.

In other words, an AMR may not only passively wait at a floor until the elevator cabin arrives at its waiting floor and opens its doors, wherein the motions of the cabin are mainly or exclusively controlled by an elevator controller and may not be influenced by the waiting AMR. Instead, the AMR may be configured to actively requesting the elevator to send its cabin to the waiting floor. Then, the AMR may enter the elevator cabin and may actively communicate with the elevator controller for requesting the cabin to be displaced to a target floor. Upon arrival at the target floor, the robot may then exit the elevator cabin. Such option for actively requesting cabin motions may emulate normal use of the elevator by a human passenger.

[0020] For realizing such option, the AMR and/or the elevator controller may be specifically adapted for communicating with each other. In principle, it is possible that the AMR uses and actuates same means as typically used by human passengers for requesting elevator actions. Typically, elevators have human-machine-interfaces (HMI) such as call buttons, car operating panels (COP) and/or landing operation panels (LOP) or other means to be actuated by a passenger or a device such as a smartcard, RFID, etc. to be handled or carried by a passenger. The AMR may use or actuate the same interfaces for requesting elevator operation. However, as machine-to-machine communication may generally be established in a different manner than human-to-machine communication, it may be preferable to provide other means for enabling communication between the AMR and the elevator controller. For example, wireless signal transmission between the AMR and the elevator controller may be established using well-known technologies such as radio transmission. Various signal transmission protocols may be applied such as Bluetooth®, or other wireless signal transmission protocols.

[0021] According to an embodiment of the present invention, the step of monitoring the functions and conditions comprises collecting and analysing data obtained by the elevator controller during the checking procedure.

[0022] In other words, while the AMRs are entering and leaving the elevator cabin at various floors during the checking procedure, thereby emulating normal passenger usage, the elevator controller may obtain data from various sensors, actuators or other devices installed throughout the elevator arrangement. For example, sensors may be arranged at an elevator drive engine, at door actuators, at a light curtain in the elevator cabin or at floor doors, etc. Such sensors may transmit their sensed signals to the elevator controller during normal operation of the elevator. Accordingly, by collecting and analysing data obtained by the elevator controller via sensors or other devices preferably being permanently installed within the elevator arrangement, information about the functions and conditions to be monitored may be obtained.

[0023] Alternatively or additionally, additional data may be generated by for example including additional sensors and/or other devices into the elevator arrangement during the checking procedure. Therein, these additional sensors or devices may be configured for measuring additional parameters which may or may not be monitored during normal operation of the elevator but which may provide valuable additional information about functions and/or conditions of the elevator to be monitored during the checking procedure. Preferably, the additional sensors or devices may be removed from the elevator arrangement after completing the checking procedure.

[0024] As a further alternative or in addition to the preceding options, according to an embodiment, the AMR comprises not only first sensors for sensing data which are required for controlling autonomous operation for the robot but the robot further comprises at least one second sensor for sensing environmental data. Therein, the step of monitoring the functions and conditions further comprises collecting and analysing environmental data sensed by such at least one second sensor of the robot during the checking procedure.

[0025] In other words, while AMRs typically comprise first sensors such as radar sensors, ultrasonic sensors, a camera and/or other suitable sensors which may provide sensing data which are required by the AMR itself for controlling its operation in an autonomous manner, an AMR may be specifically adapted for the method proposed herein by including one or more additional second sensors into the AMR. Such second sensor may sense parameters which do not necessarily have to be sensed for the AMRs autonomous operation but which may provide valuable information about the functions and conditions to be monitored during the elevator checking procedure.

[0026] For example, such second sensor may be a microphone. With such microphone, conspicuous noises or changes in a background noise may be detected during the checking procedure. Such noises or noise changes may be interpreted as resulting for example from the elevator cabin unintendedly scratching along guide rails upon being displaced throughout the elevator shaft, from malfunctions of the elevator drive engine and/or from malfunctions of actuators within elevator doors, etc.

[0027] Furthermore, an acceleration sensor may serve as a second sensor for the AMR. Such acceleration sensor may sense accelerations acting onto the elevator cabin upon the AMR travelling within the cabin. For example, such acceleration sensor may sense that the cabin does not accelerate or decelerate smoothly but that jerking occurs, such jerking influencing functions and/or conditions of the elevator or resulting from malfunctions or even failures in the elevator.

[0028] As a further example, the second sensor may be a temperature sensor. Such temperature sensor may sense temperatures within the elevator cabin or may indirectly even sense temperatures within the elevator shaft. Thereby, potential malfunctions for example within a climate control of the cabin or even heat-generating malfunctions at devices comprised in the elevator shaft may be detected.

[0029] The environmental data collected by the second sensor(s) of the AMR may be collected and stored within the AMR for further analysis by for example an external device such as for example an analysing device in a remote control centre. Alternatively, the collected data may already be analysed or at least pre-analysed within the AMR by, for example, a processing unit integrated into the AMR. Analysis results may then be provided for further use during monitoring the functions and conditions of the elevator.

[0030] According to an embodiment, motion targets of the at least one AMR throughout the various floors of the building are coordinated by a coordinator device.

[0031] In other words, the coordinator device, which may be a computer and which may be adapted for communicating with the AMR, may coordinate motion targets of the at least one AMR to be approached during the checking procedure. For example, motion targets may be specific floors of a building or parking area within such floors.

[0032] Therein, it may be emphasized that the coordinator device shall not control each and every motion of an AMR. Instead, the coordinator device may only indicate a motion target to which the AMR shall move. The coordinator device may then leave it to the AMR's autonomous operation how to reach this motion target. For example, the coordinator device may indicate to an AMR to which floor in a building it shall move next and/or, in case there are plural elevator cabins available, which elevator cabin to use during travelling to such motion target.

[0033] According to an embodiment, a plurality of AMRs is provided and motion targets of each of the robots throughout the various floors of the building are coordinated by a coordinator device.

[0034] Particularly in cases where there are multiple AMRs simultaneously operated during the checking procedure, it may be necessary to coordinate their operations at least to a specific degree such that motion targets for each of the robots are coordinated. For example, situations in which operations of single AMRs are blocked because too many AMRs are already using the elevator cabin should be avoided in order to circumvent idle times of this AMR.

[0035] According to an embodiment, motions of the at least one AMR are controlled such as to simulate motions of passengers entering and leaving the cabin during typical use conditions of the elevator.

[0036] Therein, various use scenarios may be emulated. For example, heavy usage of the elevator as it occurs during rush hours in a building may be emulated by for example operating a large plurality of AMRs simultaneously during the checking procedure. Alternatively, slight usage of the elevator may be emulated. Specifically, various usage scenarios may be emulated in a 24h-implementation of a checking procedure or, alternatively, a fast-motion implementation may be realized in a condensed 12h-scenario.

[0037] According to an embodiment, the AMR has a weight and/or outer dimensions such as to simulate corresponding characteristics of a human passenger.

[0038] Particularly, the AMR may have a weight of at least 20 kg or preferably at least 50 kg or 75 kg, such as to enable inducing substantial load variations upon the AMR entering and leaving the elevator cabin.

[0039] Optionally, the AMR may have a motion basis module including driving means, sensor means and computing means for establishing its autonomous motion capabilities. This motion basis module may have a basis weight. The motion basis module may be adapted to carry or move additional weights in order to thereby variably adapt the overall weight of the AMR. Therein, the additional weight may be arranged on, at or in the motion basis module or may be provided as separate module, possibly with separate wheels, to be pushed/pulled by the motion basis module.

[0040] Furthermore, an AMR may have outer dimensions at least roughly corresponding to those of a human passenger. For example, lateral dimensions (i.e. parallel to a standing surface of the AMR) may be in a range of a few decimetres. Accordingly, the AMR may need approximately the same space within the elevator cabin and/or may apply a similar load distribution to the cabin as a human passenger. Furthermore, a number of AMRs able to enter the elevator cabin may be substantially equal the number of human passengers intended for transportation with this elevator. A height of the AMR may typically be smaller than a height of a human passenger in order to avoid instabilities during AMR motions.

[0041] In accordance with the second aspect of the invention, embodiments of the method proposed herein may be performed by an autonomous mobile robot being specifically configured for the specific motions and actions to be performed during the checking procedure. Particularly, such AMR should be capable of moving autonomously within a floor and into and out of an elevator cabin upon a motion target being indicated for example by the coordinator device or being pre-programmed.

[0042] AMRs including a suitable hardware for such purposes have already been developed. For example, the company AETHON (see http://www.aethon.com) has developed AMRs referred to as "tugs" which are adapted for transportation tasks for example in hospitals and which are described for example in US 2010/0234990 A1.

[0043] While the hardware of such AMRs may be already available, a computer program product, i.e. software, may be applied for instructing the AMR to performing the method described herein. Such software may be programmed in an arbitrary programming language and may be adapted to specific requirements of the AMR.

[0044] The computer program product may be stored on any type of computer-readable medium such as on flash memory, magnetic memories such as hard disc drives, RAM, ROM, PROM, EPROM, etc. Alternatively, the computer program product may be stored in a server computer and may be provided via a download to an AMR via a network such as the Internet.

[0045] It shall be noted that possible features and advantages of embodiments of the invention are described herein partly with respect to a method for checking functions and conditions of an elevator and partly with respect to an autonomous mobile robot configured for performing such method. One skilled in the art will recognize that the features may be suitably transferred from one embodiment to another and features may be modified, adapted, combined and/or replaced, etc. in order to come to further embodiments of the invention.

[0046] In the following, advantageous embodiments of the invention will be described with reference to the enclosed drawing. However, neither the drawing nor the description shall be interpreted as limiting the invention.

[0047] Fig. 1 shows an elevator with autonomous mobile robots being configured for performing the checking method according to an embodiment of the present invention.

[0048] The figure is only schematic and not to scale.

[0049] Fig. 1 shows an elevator 1 and several autonomous mobile robots (AMR) 2 with which a method for checking functions and conditions of the elevator 1 may be performed in accordance with an embodiment of the present invention.

[0050] The elevator 1 comprises an elevator car 3 and a counterweight 5 arranged in an elevator shaft 7. The elevator cabin 3 and the counterweight 5 are suspended by a suspension traction means 9 comprising several ropes or belts. The suspension traction means 9 is driven by a traction sheave 13 of a drive engine 11. An operation of the drive engine 11 is controlled by an elevator controller 15. The cabin 3 may be driven to various floors 29 where shaft doors 27 may open and close an access to the cabin 3. Landing operation panels (LOP) 23 are provided in each of the floors 29 close to the shaft doors 27 such that passengers may request a displacement of the cabin 3 to their waiting floor 29. A car operation panel (COP) 25 is provided inside the cabin 3 and may be used by passengers to indicate their target floor 29. The LOPs 23 and the COP 25 are connected to the elevator controller 29 for signal transmission, either by hard-wiring or wireless.

[0051] Under certain circumstances, functions and conditions in the elevator 1 may have to be checked. For example, such checking may be helpful upon developing new elevator systems. Furthermore, such checking may be part of a final inspection after installation of an elevator system in a client's building, i.e. before approval and starting operation of the elevator. Furthermore, upon malfunctions occurring in the elevator and/or in regular time intervals, systematically checking functions and conditions of the elevator may help e.g. in detecting reasons for such malfunctions.

[0052] While, conventionally, checking procedures were conducted with the cabin 3 being empty or being in a stationary load condition, it is proposed herein to conduct such checking procedures while AMRs are entering into and leaving from the cabin 3, thereby inducing load variations within the cabin 3. Thereby, not only functions of the elevator's drive system including the drive engine 11, the suspension traction means 9, the elevator controller 15, etc. may be checked but also other components may be checked such as a light curtain for monitoring a door region of the shaft doors 27, brakes for fixing the cabin 3 in a correctly levelled position relative to one of the floors 29 upon passengers entering or leaving, systems for determining a load condition in the cabin 3, etc.

[0053] An AMR 2 may communicate with the elevator 1, particularly with the controller 15 of the elevator 1, for example via an AMR-elevator interface 20. The AMR-elevator interface 20 may for example use radio signals for indicating to the elevator 1 that the cabin 3 shall be sent to a specific floor 29, such as a floor where the AMR 2 is currently waiting or a target floor 29 to which the AMR 2 shall travel.

[0054] In order to enable an AMR 2 to autonomously operating and moving between the floors 29 and the cabin 3, each AMR 2 comprises a multiplicity of first sensors 19. Inter alia, the first sensors 19 may sense parameters such as distances to obstacles or walls. Such first sensors 19 may include for example radar sensors, ultrasonic sensors, cameras, capacitive sensors, etc. Data from such first sensors 19 may be transmitted to a central processing unit (CPU) 17 of the AMR 2. Accordingly, taking into account such data from the first sensors 19, the AMR 2 may move autonomously throughout the building and use the elevator cabin 3 in order to finally reach motion targets such as another floor.

[0055] For conducting the checking method described herein, a checking procedure may be initiated during which, on the one hand, functions and conditions of the elevator are continuously or repeatedly monitored and, on the other hand, the AMRs 2 are instructed to repeatedly enter the cabin 3 at floors 29 and leave the cabin 3 at other floors 29 in order to thereby emulate passenger movement and induce load changes in the cabin 3. Therein, motion targets of the AMRs 2 may be coordinated by a coordinator device 31. Such coordinator device 31 be included e.g. in the cabin 3 during performing the checking procedure.

[0056] The coordinator device 31 may be a computer powerful enough to run a requisite software to control the system. A raspberry pi or a standard PC laptop may be used for the coordinator device 31. The coordinator device 31 may be connected to a power outlet provided by the elevator cabin 3. A backup battery may be added in case of power loss within the elevator shaft 7. The coordinator device 31 may have peripherals, such as a mouse and/or a keyboard, and/or interfaces to external devices/peripherals as needed, depending on a user's preferred method of interaction. The coordinator device 31 may be connected to a COP CAN (controller area network) panel of the elevator 1 for example by means of a USB interfacing device. Alternatively, hard wired or wireless connection may be established to specific elevator networks typically implemented by an elevator producer. The coordinator device can also be placed near the controller 15 of the elevator 1. Then the coordinator device may be connected to the controller 15 of the elevator 1 for example by means of a USB interfacing device.

[0057] A plurality of AMRs 2 may be applied throughout the various floors 29 during the checking procedure. The

AMRs 2 may all be identical and may be based on a simple differential drive platform or basis module optimized for object avoidance. Differentiation between AMRs during operation may be established through software IDs assigned to each robot. Each robot may have its own power source such as a battery in order to be able to move independently from any grid-based power source throughout the building. Charging ports may be provided within the building, e.g. in specific parking areas, and the AMRs may be adapted to autonomously move to and/or couple to such charging ports.

[0058] Each AMR 2 may have additional second sensors 21. These second sensors 21 are not necessarily required for the AMRs autonomous operation but may sense environmental data relating to the functions and conditions of the elevator 1 to be checked.

[0059] For example, acceleration sensors may sense an acceleration of the AMR 2 and, thereby, may indirectly measure an acceleration of the elevator car 3 accessed by the AMR 2. A second sensor comprising a microphone may sense any abnormal noises occurring during operation of the elevator 1.

[0060] Data and signals from such second sensors 21 may be transmitted to the central processing unit 17 of the AMR 2 for further processing and analysis thereof and/or may be stored within memory comprised in the AMR 2 such as to be further processed and analysed at a later stage, optionally in an evaluation device remote to the AMR 2.

[0061] Possible details of an embodiment of the checking method will now be described with respect to the example of testing a new elevator installation. Beforehand, testing floors may be checked to allow adequate space for the AMRs to operate. A parking area may be established on one of the floors 29. Dimensions of the parking area and its distance from the elevator shaft 7 and its shaft doors 27 may be measured in advance. The coordinator device 31 and a number of AMRs 2 are brought to the site. The coordinator device 31 is placed inside the elevator 1 and is powered on before the AMRs 2. A user may log into the coordinator device 31, either on the device or remotely, to enter current elevator information. For example, a type of the elevator 1 may be entered into the coordinator device 31. The coordinator device 31 may use internal information to determine the dimensions of the elevator 1 and a maximum number of AMRs 2 that can be utilized at once. Dimensions and a location of the parking area with respect to the elevator 1 may be entered into the coordinator device 31. Each AMR 2 is then turned on and communicates with the coordinator device 31 to register it within the system. The AMRs 2 are initially localized by placing them within the elevator 1. After registration and localization, each AMR 2 is sent to the parking area. Optionally, an AMR can traverse the parking area to ensure that there are no obstacles in the area and the AMR 2 may navigate successfully to the parking area. Once all the AMRs are sent to the parking area, the system is ready to start. The AMRs 2 remember their location initially, in case the system is set up for later use and shut down in the meantime. A simulation scenario may be chosen by the coordinator device 31. When a start command is issued, the coordinator device 31 will begin issuing movement commands and elevator calls to simulate the system. When the simulation is finished or issued a stop command, the coordinator device 31 may bring all of the AMRs 2 down to the parking floor. The registry of the AMRs 2 and their positions may be stored in the coordinator device 31 so that this information is not lost when powered off. The AMRs 2 may also remember their last known location to assume their position when restarted. If a simulation suddenly stops due to e. g. a critical error, the AMRs shall be notified and stop in place. When restarted, the simulation shall attempt to bring all AMRs 2 to the parking floor and park them so that another operation may be started.

[0062] Finally, some possible features of the proposed checking method as well as of the proposed devices and AMRs 2 configured for implementing such checking method shall be briefly stated:

- A range to apply the checking procedure, i.e. to apply endurance testing, with robots shall go up to 700 feet. Such range may depend on a wireless range of devices. If a central controller device 31 is used in the cabin 3, and only AMRs 2 within its range (for example in the same floor 29) are controlled, then the system could have an infinite range, i.e. the system could work for any height of the elevator 1. Robots outside the wireless range or on different floors 29 may lock in place while the system is in operation.
- No permanent mechanical modification to the cabin 3 shall be needed. All stationary devices might be plug-and-play into the COP 25 and may be easily clamped or self-supplying. Nothing should require drilling, but glue may be okay.
- Preferably, all testing equipment should be removable such that no fixtures, sensors, etc. shall be needed on any of the floors 29. Preferably, all immobile parts of the system should be inside the cabin 3 (except for any charging station). If AMRs 2 communicate with a local controller device 31, such controller device 31 should therefore be inside the cabin 3. Otherwise, AMRs 2 need to use for example a WiFi network within the tower to communicate.
- The weight of a single AMR 2 may be between 20 and 200 kg, preferably between 50 and 150 kg. The height of a single AMR 2 should preferably not exceed 2 feet 6 inch while the lateral robot dimensions should be greater than 12 by 12 inches but preferably should not exceed 18 by 18 inches. Thereby, the AMR 2 may be very sturdy and not allowed to tip over easily.
- Each robot may have its own power supply using for example batteries which shall last for e.g. up to 72 hours.
- The AMRs 2 shall stop moving immediately when

out of control.

[0063] Summarizing, with embodiments of the method proposed herein, the autonomous mobile robots 2 may emulate e.g. normal use of the elevator 1 by passengers including load changes in the cabin 3 induced by entering or leaving passengers. Thereby, the functions and conditions of the elevator 1 may be monitored under more realistic conditions and therefore the functions and conditions may be checked with higher reliability.

[0064] Finally, it should be noted that the term "comprising" does not exclude other elements or steps and the "a" or "an" does not exclude a plurality. Also elements described in association with different embodiments may be combined. It should also be noted that reference signs in the claims should not be construed as limiting the scope of the claims.

Claims

1. Method for checking functions and conditions of an elevator (1), comprising the following steps:

- providing at least one autonomous mobile robot (2), the robot being adapted to autonomously moving from a floor (29) of a building into a cabin (3) of the elevator (1) and vice versa;
- performing a checking procedure during which the cabin (3) of the elevator (1) is displaced multiple times between various floors (29) of the building and the at least one autonomous mobile robot (2) repeatedly enters and leaves the cabin (3) at various floors (29);
- monitoring the functions and conditions of the elevator (1) during the checking procedure.

2. Method of claim 1, wherein the autonomous mobile robot (2) is further adapted to communicate with the elevator (1) such as to transmit requests to the elevator (1) for displacing the cabin (3) to an intended floor (29), wherein, during the checking procedure, the at least one autonomous mobile robot (2) repeatedly requests the cabin (3) to come to a floor (29) where the autonomous mobile robot (2) is currently waiting, then the autonomous mobile robot (2) enters the cabin (3) and requests the cabin (3) to be displaced to another floor (29) and then the autonomous mobile robot (2) exits the cabin (3) at the other floor (29).

3. Method of one of claims 1 and 2, wherein the step of monitoring the functions and conditions further comprises collecting and analysing data obtained by an elevator controller (15) during the checking procedure.

4. Method of one of the preceding claims, wherein the autonomous mobile robot (2) comprises first sensors (19) for sensing data which are required for controlling autonomous operation for the autonomous mobile robot (2) and wherein the autonomous mobile robot (2) further comprises at least one second sensor (21) for sensing environmental data and wherein the step of monitoring the functions and conditions further comprises collecting and analysing environmental data sensed by the autonomous mobile robot's at least one second sensor (21) during the checking procedure.

5. Method of one of the preceding claims, wherein motion targets of the at least one autonomous mobile robot (2) throughout the various floors of the building are coordinated by a coordinator device (31).

6. Method of one of the preceding claims, wherein a plurality of autonomous mobile robots (2) is provided and motion targets of each of the autonomous mobile robots (2) throughout the various floors (29) of the building are coordinated by a coordinator device (31).

7. Method of one of the preceding claims, wherein motions of the at least one autonomous mobile robot (2) are controlled such as to simulate motions of passengers entering and leaving the cabin (3) during typical use conditions of the elevator (1).

8. Method of one of the preceding claims, wherein the autonomous mobile robot (2) has at least one of a weight and outer dimensions such as to simulate corresponding characteristics of a human passenger.

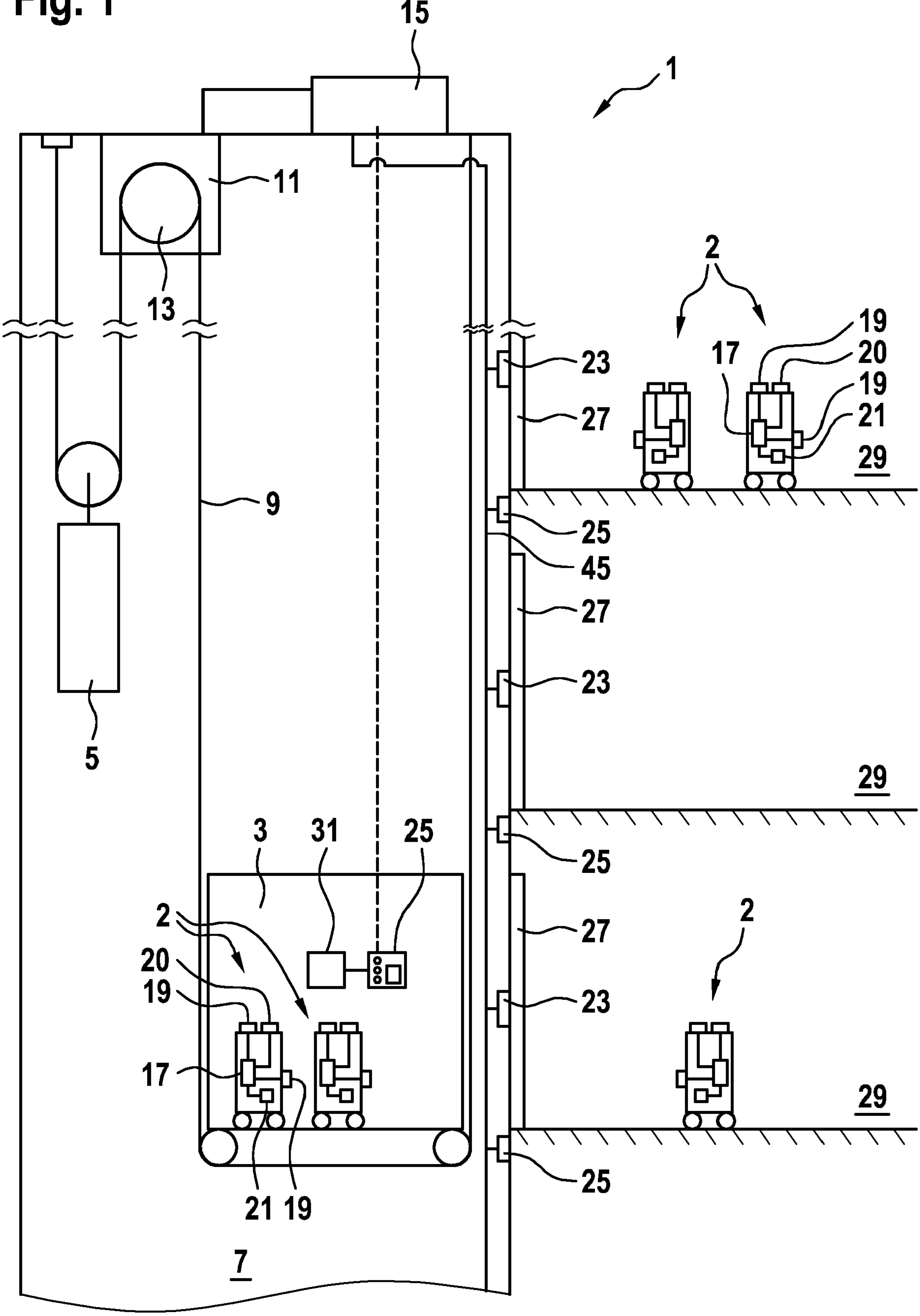
9. Method of one of the preceding claims, wherein the autonomous mobile robot has a weight of at least 20kg.

10. Autonomous mobile robot (2) configured to perform a method according to one of claims 1 to 9.

11. Computer program product comprising instructions which, when executed in a programmable control of an autonomous mobile robot (2), instruct the autonomous mobile robot (2) to perform a method according to one of claims 1 to 9.

12. Computer readable medium comprising a computer program product according to claim 11 stored thereon.

Fig. 1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EUROPEAN SEARCH REPORT

Application Number
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