

the physical environment relative to the specified job location for the job request. Thus, what is needed is a job management system for processing job requests in an environment wherein the mobile robots in the fleet are heterogeneous and have a diverse collection of capabilities and functions.

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Summary Of The Invention

The job management system (JMS) of the present invention receives, coordinates and manages job requests in a physical environment, such as a factory, order processing facility, distribution center, hospital or office building. The job management system receives and prioritizes the job requests, and selects individual units from a fleet of one or more
10 heterogeneous autonomously-navigating mobile robotic units to carry out the job requests. The job requests for the mobile robots may specify a virtual (i.e., mapped job location) representing an actual job location in the physical environment, or a virtual (mapped) job operation representing an actual job operation in the physical environment, ~~or~~ but not both a the virtual job location and a the virtual job operation. The job management system
15 automatically determines the actual job locations and job operations associated with the virtual job locations and operations, and automatically selects a suitable mobile robot from the fleet to handle each job request.

In some embodiments, the job management system selects the mobile robot to handle the job request based on the selected mobile robot's current status, the selected mobile
20 robot's current configuration, or both the current status and the current configuration for the selected mobile robot. The job management system also sends one or more commands to the selected mobile robot to cause the selected mobile robot to automatically drive to the actual job location, if necessary, and to automatically perform the actual job operation. In some cases, the job management system sends one or more commands that cause the selected
25 mobile robot to execute both steps of driving to the actual job location and performing the requested job operation.

The job operations may encompass any task suitable for performance by a mobile or industrial robot, including for example, picking up, transporting and dropping off objects and materials, as well as other tasks unrelated to transporting objects and materials, such as
30 drilling, stamping or cutting an object, or cleaning up (sanitizing or disinfecting) an area. Accordingly, the mobile robots in the fleet may have different physical configurations,

management system comprises a memory; a microprocessor coupled to the memory; a map (or map file) stored in the memory to define a floor plan corresponding to the physical environment; a queue manager that operates cooperatively with the microprocessor and the memory to select a mobile robot from the fleet and to determine an actual job location and/or an actual job operation associated with the request, all in accordance with the map, and a network interface device to transmit one or more commands to the selected mobile robot to make the selected robot carry out the job request. The map also defines a set of virtual job locations in respect to the floor plan, each virtual job location representing an actual job location in the physical environment, and also associates a set of virtual job operations with one or more of the virtual job locations in the set of virtual job locations, each virtual job operation representing an actual job operation in the physical environment. For example, the system operator may create and place a virtual job location on the floor plan called "battery charging station," which represents an actual battery charging station on the factory floor of the real world physical environment. The system operator may further create a virtual job operation, called "charge batteries," and associate the newly-created virtual job operation ("charge batteries") with the newly created virtual job location ("battery charging station"). Subsequently, copies of the map with the virtual job location and virtual job operation may be used by the mobile robots so that the mobile robots will automatically know that they should start executing the "charge batteries" job operation upon being sent or summoned to the "battery charging station" job location. It is to be understood that, depending on the situation, some virtual job locations may have no associated virtual job operations, while other virtual job locations may have one, dozens or even hundreds of associated virtual job operations.

When the queue manager on the job management system receives a job request, the job request may specify either (1) a virtual job location without specifying a virtual job operation, or (2) a virtual job operation without specifying a virtual job location, ~~or~~ but not both (3) ~~at~~ the virtual job location *and* ~~at~~ the virtual job operation. If the request contains only a virtual job location, then the job management system of the present invention will use the map and the specified virtual job location to determine the actual job operation in the physical environment for the job request. Put another way, the map tells the job management system which virtual job operations, if any, are associated with the specified virtual job location. The map also tells the job management system (as well as the mobile robots) the

actual job location in the physical environment. If the request contains only a virtual job operation, then the job

request and, in that case, automatically delay selecting a mobile robot from the fleet to handle the job request until a mobile robot from the fleet becomes available. Additionally, in specific embodiments of the method, the queue manager could receive a signal indicating that the selected mobile robot failed to handle the job request and, in that case, automatically
5 select a different mobile robot from the fleet to handle the job request based on the status profile and the configuration profile stored in the memory for the different mobile robot.

There is provided a method for processing job requests on a job management system in a physical environment is provided. The first step in the method comprises the step of storing in a memory a map defining a floor plan for the physical environment, a virtual job
10 location in respect to the floor plan, the virtual job location representing an actual job location in the physical environment, and associating one or more virtual job operations with the virtual job location, each virtual job operation representing an actual job operation in the physical environment. Next, the method stores in the memory a status profile and a configuration profile for each mobile robot in the fleet, and receives a job request by the
15 queue manager, the job request comprising either a specified job operation, or a specified job location, or—but not both the job location and the job operation. In the next step of the method, the queue manager automatically selects a mobile robot from the fleet to handle the received job request based on a status profile and a configuration profile stored in the memory for the selected mobile robot. And finally, in the last step, a network interface is
20 used to automatically transmit over a command instruction to the selected mobile robot to cause the selected mobile robot to automatically drive to the actual job location in accordance with the floor plan, to automatically perform the actual job operation, or both drive to the actual job location and perform the actual job operation.

In accordance with one aspect of the present invention, there is provided a method of
25 processing job requests on a job management system in a physical environment comprising the job management system and a fleet of mobile robots, the job management system including a queue manager, a memory and a network interface, the method comprising: a) storing in the memory a map that (i) defines a floor plan corresponding to the physical environment, (ii) defines a virtual job location in respect to the floor plan, the virtual job
30 location representing an actual job location in the physical environment, and (iii) associates a virtual job operation with the virtual job location, the virtual job operation representing an actual job operation in the physical environment; b) receiving a job request by the queue

manager, wherein the job request including includes either the virtual job location on the map, or the virtual job operation on the map, ~~or~~ but not both the virtual job location and the virtual job operation; c) with the queue manager, automatically selecting a mobile robot from the fleet to handle the received job request; and d) transmitting one or more commands to the selected mobile robot via the network interface to cause the selected mobile robot (A) to automatically drive to the actual job location ~~represented by the virtual job location~~, (B) to automatically execute the actual job operation ~~represented by the virtual job operation~~, or (C) to automatically carry out both (A) and (B); e) wherein, if the job request does not include the virtual job location, then the queue manager determines the actual job location based on the map and the virtual job operation, and f) if the job request does not include the virtual job operation, then the queue manager determines the actual job operation based on the map and the virtual job location.

In accordance with another aspect of the present invention, there is provided a job management system for processing job requests in a physical environment comprising a fleet of mobile robots, the job management system comprising: a) a memory; b) a microprocessor coupled to the memory; c) a queue manager, operable with the microprocessor and the memory to: (i) store in the memory a map that (A) defines a floor plan corresponding to the physical environment, (B) defines a virtual job location in respect to the floor plan, the virtual job location representing an actual job location in the physical environment, and (C) associates a virtual job operation with the virtual job location, the virtual job operation representing an actual job operation in the physical environment, (ii) receive a job request, wherein the job request including includes either the virtual job operation on the map, or the virtual job location on the map, ~~or~~ but not both the virtual job location and the virtual job operation, (iii) automatically select a mobile robot from the fleet to handle the received job request, (iv) automatically determine the actual job location based on the map and the virtual job operation if the job request does not include the virtual job location, and (v) automatically determine the actual job operation based on the map and the virtual job location if the job request does not include the virtual job operation; and d) a network interface to transmit one or more commands from the queue manager to the selected mobile robot to cause the selected mobile robot to (i) automatically drive to the actual job location ~~represented by the virtual job location~~, (ii) automatically execute the actual job operation ~~represented by the virtual job operation~~, or (iii) automatically carry out both d)(i) and d)(ii).

In still another aspect of the present invention, there is provided a non-transitory computer-readable storage medium, such as a hard drive, flash memory device, CDROM or other memory-storage device, the storage medium having an executable program for processing job requests in a physical environment comprising a fleet of mobile robots. The executable program includes a collection of program instructions that, when executed by one or more microprocessors on a computer system, will cause the microprocessors to: (a) store in a memory device on the computer system a map that (i) defines a floor plan corresponding to the physical environment, (ii) defines a virtual job location in respect to the floor plan, the virtual job location representing an actual job location in the physical environment, and (iii)

associates a virtual job operation with the virtual job location, the virtual job operation representing an actual job operation in the physical environment. The program instructions are further arranged to cause the computer system to receive a job request, wherein the job request ~~including~~ includes either the virtual job operation on the map, or the virtual job location on the map, or ~~but not both the virtual job location and the virtual job operation.~~

Then the program instructions will cause the computer system: to automatically select a mobile robot from the fleet to handle the received job request; to automatically determine the actual job location based on the map and the virtual job operation if the job request does not include the virtual job location; to automatically determine the actual job operation based on the map and the virtual job location if the job request does not include the virtual job operation; and to transmit one or more commands from the computer system to the selected mobile robot to cause the selected mobile robot to (i) automatically drive to the actual job location ~~represented by the virtual job location~~, (ii) automatically execute the actual job operation ~~represented by the virtual job operation~~, or (iii) automatically carry out both steps of driving to the actual job location and performing the actual job operation.

Brief Description of the Figures

The accompanying drawings, which are incorporated in and constitute part of the specification, illustrate preferred embodiments of the invention, and, together with the description, serve to explain the principles of the present invention. In the drawings, like reference numbers indicate identical or functionally-similar elements.

FIG. 1 shows a diagram illustrating an example of a physical environment in which a job management system of the present invention may be beneficially deployed to receive, manage, process and assign incoming job requests, where the physical environment includes a fleet of mobile robots for handling the incoming job requests.

FIG. 2 shows a high-level block diagram illustrating the major functional components of a job management system configured to operate, in accordance with an exemplary embodiment of the present invention, within a factory automation system that includes a fleet of mobile robots.

FIG. 3 illustrates, by way of example, some of the data content of a map file defining a floor plan for the physical environment. The map file is stored in the memory of the mobile robot according to embodiments of the invention.

What is claimed is:

1. A method of processing job requests on a job management system in a physical environment comprising the job management system and a fleet of mobile robots, the job management system including a queue manager, a memory and a network interface, the method comprising:

- a) storing in the memory a map that (i) defines a floor plan corresponding to the physical environment, (ii) defines a virtual job location in respect to the floor plan, the virtual job location representing an actual job location in the physical environment, and (iii) associates a virtual job operation with the virtual job location, the virtual job operation representing an actual job operation in the physical environment;
- b) receiving a job request by the queue manager, wherein the job request including includes either the virtual job location on the map, or the virtual job operation on the map, or but not both the virtual job location and the virtual job operation;
- c) with the queue manager, automatically selecting a mobile robot from the fleet to handle the received job request; and
- d) transmitting one or more commands to the selected mobile robot via the network interface to cause the selected mobile robot (A) to automatically drive to the actual job location ~~represented by the virtual job location~~, (B) to automatically execute the actual job operation ~~represented by the virtual job operation~~, or (C) to automatically carry out both (A) and (B);
- e) wherein, if the job request does not include the virtual job location, then the queue manager determines the actual job location based on the map and the virtual job operation, and
- f) if the job request does not include the virtual job operation, then the queue manager determines the actual job operation based on the map and the virtual job location.

2. The method of claim 1, further comprising:

- a) storing in the memory a status profile for each mobile robot in the fleet, the status profile defining a current status for said each mobile robot;

- b) determining by the queue manager, based on the configuration profile stored in the memory for the selected mobile robot, that the current configuration for the selected mobile robot is compatible with the specified time for performance.

18. The method of claim ~~13~~2, further comprising:

- a) receiving by the queue manager a specified priority for the job request; and
- b) determining by the queue manager, based on the status profile for the selected mobile robot, that the current status for the selected mobile robot is compatible with the specified priority.

19. The method of claim 13, further comprising:

- a) receiving by the queue manager a specified priority for the job request; and
- b) determining by the queue manager, based on the current configuration profile stored in memory for the selected mobile robot, that the current configuration for the selected mobile robot is compatible with the specified priority.

20. The method of claim 13, further comprising:

- a) receiving by the queue manager a specified combination of job locations and job operations; and
- b) determining by the queue manager, based on the current configuration profile stored in memory for the selected mobile robot, that the current configuration for the selected mobile robot is compatible with the specified combination.

21. The method of claim 13, further comprising:

- a) receiving by the queue manager a specified route that the selected mobile robot will use to drive to the actual job location; and
- b) determining by the queue manager, based on the current configuration profile stored in memory for the selected mobile robot, that the current configuration for the selected mobile robot is compatible with the specified route.

- b) automatically delaying, by the queue manager, selection of a mobile robot from the fleet to handle the job request until a mobile robot from the fleet becomes available.

28. The method of claim 1, further comprising:

- c) receiving, by the queue manager, a signal that the selected mobile robot failed to handle the job request; and
- d) automatically selecting, with the queue manager, a different mobile robot from the fleet to handle the job request, wherein the queue manager selects the different mobile robot based on the status profile and the configuration profile stored in the memory for the different mobile robot.

29. A job management system for processing job requests in a physical environment comprising a fleet of mobile robots, the job management system comprising:

- a) a memory;
- b) a microprocessor coupled to the memory;
- c) a queue manager, operable with the microprocessor and the memory to:
 - (i) store in the memory a map that (A) defines a floor plan corresponding to the physical environment, (B) defines a virtual job location in respect to the floor plan, the virtual job location representing an actual job location in the physical environment, and (C) associates a virtual job operation with the virtual job location, the virtual job operation representing an actual job operation in the physical environment,
 - (ii) receive a job request, wherein the job request including includes either the virtual job operation on the map, or the virtual job location on the map, or but not both the virtual job location and the virtual job operation,
 - (iii) automatically select a mobile robot from the fleet to handle the received job request,
 - (iv) automatically determine the actual job location based on the map and the virtual job operation if the job request does not include the virtual job location, and

- (v) automatically determine the actual job operation based on the map and the virtual job location if the job request does not include the virtual job operation; and
- d) a network interface to transmit one or more commands from the queue manager to the selected mobile robot to cause the selected mobile robot to (i) automatically drive to the actual job location ~~represented by the virtual job location~~, (ii) automatically execute the actual job operation ~~represented by the virtual job operation~~, or (iii) automatically carry out both d)(i) and d)(ii).

30. The job management system of claim 29, further comprising:

- a) a status profile stored in the memory for each mobile robot in the fleet, the status profile defining a current status for said each mobile robot;
- b) wherein the queue manager determines, based on the status profile for the selected mobile robot, that the current status for the selected mobile robot is compatible with the job request.

31. The job management system of claim 30, wherein the status profile comprises one or more of: a robot identifier, a robot position, a robot heading, a current robot speed, a current job identifier, a current job status, a current job location, a proximity to the current job location, a current job destination path, an estimated time of arrival, an estimated time of departure, a robot idle time, a robot performance level, a robot security level, a robot battery charge level, a robot payload status, a robot payload error condition, a robot cargo status, and a robot cargo capacity.

32. The job management system of claim 30, further comprising:

- a) a status-based preference criteria; and
- b) the queue manager is further configured to select the mobile robot in accordance with the status-based preference criteria if two or more mobile robots in the fleet have current statuses that are compatible with the job request.

33. The job management system of claim 32, wherein the queue manager automatically compares the status profiles for said two or more mobile robots to identify which of said two or more mobile robots has a more favorable status profile for the actual job location.

44. The job management system of claim 43, wherein the queue manager is further configured to compare the configuration profiles for said two or more mobile robots to identify which of said two or more mobile robots has a more favorable configuration profile for the actual job operation.

45. The job management system of claim 41, wherein:

- a) the queue manager receives a specified time for performance of the job request; and
- b) the queue manager determines, based on the configuration profile stored in the memory for the selected mobile robot, that the current configuration for the selected mobile robot is compatible with the specified time for performance.

46. The job management system of claim ~~41~~30, wherein:

- a) the queue manager receives a specified priority for the job request; and
- b) the queue manager determines, based on the status profile for the selected mobile robot, that the current status for the selected mobile robot is compatible with the specified priority.

47. The job management system of claim 41, wherein:

- a) the queue manager receives a specified priority for the job request; and
- b) the queue manager determines, based on the current configuration profile stored in memory for the selected mobile robot, that the current configuration for the selected mobile robot is compatible with the specified priority.

48. The job management system of claim 41, wherein:

- a) the queue manager receives a specified combination of job locations and job operations; and
- b) the queue manager determines, based on the current configuration profile stored in memory for the selected mobile robot, that the current configuration for the selected mobile robot is compatible with the specified combination.

- d) responsive to detecting the intersection, the queue manager selects a different mobile robot to handle the job request.

55. The job management system of claim 29, wherein:

- a) the queue manager receives a signal that no mobile robot in the fleet is available to handle the job request; and
- b) the queue manager automatically delays selection of a mobile robot from the fleet to handle the job request until a mobile robot from the fleet becomes available.

56. The job management system of claim 29, wherein:

- a) the queue manager receives a signal that the selected mobile robot failed to handle the job request; and
- b) the queue manager automatically selects a different mobile robot from the fleet to handle the job request.

57. A non-transitory computer-readable storage medium with an executable program for processing job requests in a physical environment comprising a fleet of mobile robots, wherein the executable program comprises program instructions to cause one or more microprocessors on a computer system to:

- a) store in a memory device on the computer system a map that (i) defines a floor plan corresponding to the physical environment, (ii) defines a virtual job location in respect to the floor plan, the virtual job location representing an actual job location in the physical environment, and (iii) associates a virtual job operation with the virtual job location, the virtual job operation representing an actual job operation in the physical environment;
- b) receive on the computer system a job request, wherein the job request including includes either the virtual job operation on the map, or the virtual job location on the map, or but not both the virtual job location and the virtual job operation;
- c) automatically select a mobile robot from the fleet to handle the received job request;

- d) automatically determine the actual job location based on the map and the virtual job operation if the job request does not include the virtual job location;

- e) automatically determine the actual job operation based on the map and the virtual job location if the job request does not include the virtual job operation; and
- f) transmit one or more commands from the computer system to the selected mobile robot to cause the selected mobile robot to (i) automatically drive to the actual job location ~~represented by the virtual job location~~, (ii) automatically execute the actual job operation ~~represented by the virtual job operation~~, or (iii) automatically carry out both f)(i) and f)(ii).

58. The non-transitory computer-readable storage medium of claim 57, wherein the executable program further includes program instructions to cause said one or more microprocessors to:

- a) store a status profile in the memory for each mobile robot in the fleet, the status profile defining a current status for said each mobile robot; and
- b) determine, based on the status profile for the selected mobile robot, that the current status for the selected mobile robot is compatible with the job request.

59. The non-transitory computer-readable storage medium of claim 58, wherein the status profile comprises one or more of: a robot identifier, a robot position, a robot heading, a current robot speed, a current job identifier, a current job status, a current job location, a proximity to the current job location, a current job destination path, an estimated time of arrival, an estimated time of departure, a robot idle time, a robot performance level, a robot security level, a robot battery charge level, a robot payload status, a robot payload error condition, a robot cargo status, and a robot cargo capacity.

60. The non-transitory computer-readable storage medium of claim 58, wherein the executable program further includes program instructions to cause said one or more microprocessors to:

- a) store in the memory a status-based preference criteria; and
- b) select the mobile robot in accordance with the status-based preference criteria if two or more mobile robots in the fleet have current statuses that are compatible with the job request.