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(71) Applicant: **ABB Research Ltd.**
8050 Zürich (CH)

(72) Inventors:
- **Sjöberg, Johan**
  723 44, Västerås (SE)
- **Öhr, Jonas**
  744 32, Heby (SE)
- **Lundin, Johan**
  75258, Västerås (SE)

(74) Representative: **Johansson Webjörn, Ingmari**
ABB AB
Intellectual Property
Ingenjör Bååths Gata 11
721 83 Västerås (SE)

(54) Calculation of collision avoiding trajectory

(57) A method is presented of calculating a trajectory for a crane (50) to move a load (12) from a starting position (11a) to a destination position (11b). The method comprises the steps of: obtaining (60) data representing obstacles (15a-e) restricting a path from the starting position to the destination position of the load; calculating (62) a trajectory (22) for the load to follow. The step of calculating includes the use of a two dimensional geometrical model (5), wherein the model comprises a first set of geometrical figures (30a,30b,30c,30e), wherein each geometrical figure of the first set corresponds in position to a side (17a,17b,17c,17e) of one of the obstacles, and a second geometrical figure (31) representing potential positions of the load in the case of swinging, wherein the trajectory is calculated such that the second geometrical figure avoids intersecting any of the geometrical figures of the first set.

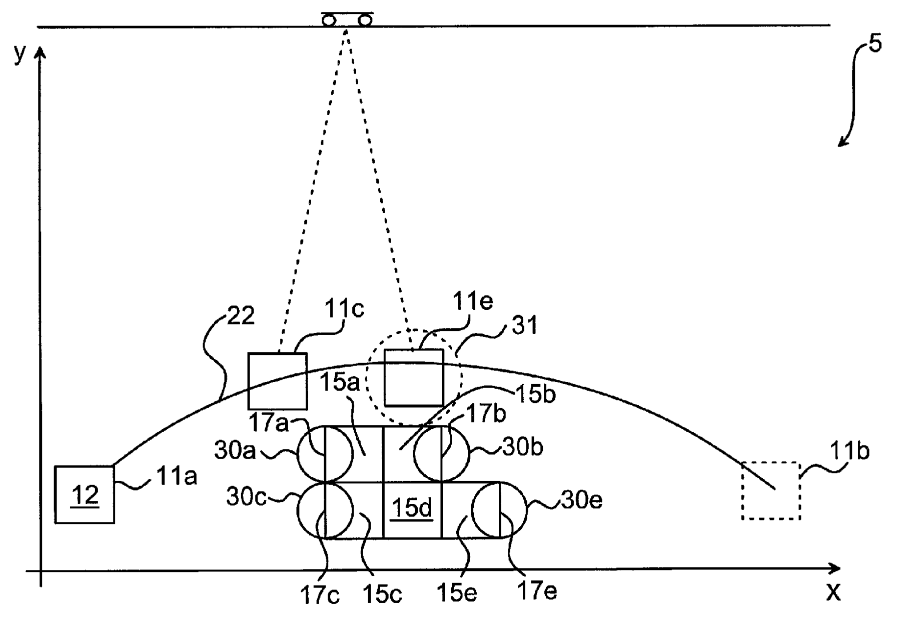

Fig. 3

EP 2 402 280 A1

Description

FIELD OF INVENTION

[0001] The present invention relates generally to trajectory calculation for crane carried loads, and more particularly to avoiding collisions in such trajectory calculation.

BACKGROUND

[0002] In harbours, ships are loaded and unloaded with cranes. Cranes are used both for container movements and for bulk goods movement.

[0003] When planning movement of a load from one point to another, there are typically conflicting objectives. On one hand, it is usually desired to effect the movement with a minimum duration. On the other hand, any obstacles between the start point and the end point need to be avoided, which of course, takes time.

[0004] US-6,065,619 presents a cargo handling path setting method and apparatus. A theoretical simulation test (calculation) is performed based on set conditions to compute a cargo handling path for a suspended load and the amount of swing of the suspended load (including that when an abnormality occurred and the trolley stopped abruptly). In the case of a calculated collision, the traversing starting time point and the lowering starting time point are slightly delayed, or other set values are properly revised, and a theoretical simulation test is conducted again. This procedure is repeated to set a cargo handling path for the state of the obstacles present in the way during carriage.

[0005] However, any improvement in the trajectory calculation is beneficial as it can reduce time for movements and/or more securely avoid collisions.

SUMMARY

[0006] An object of the present invention is to improve calculation of trajectories for loads moved by cranes.

[0007] According to a first aspect of the invention, it is presented a method of calculating a trajectory for a crane to move a load from a starting position to a destination position. The method comprises the steps of: obtaining data representing obstacles restricting a path from the starting position to the destination position of the load; calculating a trajectory for the load to follow. The step of calculating includes the use of a two dimensional geometrical model, wherein the model comprises a first set of geometrical figures, wherein each geometrical figure of the first set corresponds in position to a side of one of the obstacles, and a second geometrical figure representing potential positions of the load in the case of swinging, wherein the trajectory is calculated such that the second geometrical figure avoids intersecting any of the geometrical figures of the first set.

[0008] The second geometrical figure may be fixed to a calculated opposite swing position of the load for a plurality of potential load positions of the trajectory, wherein the plurality of potential load positions are for a plurality points in time.

[0009] Any side of the obstacles may correspond to at most one geometrical figure of the first set. In other words, there are no duplicates of geometric figures representing a side of an obstacle.

[0010] The method may further comprise the step of sending signals to effect movement of the crane according to the calculated trajectory.

[0011] The second geometrical figure may be a circle containing potential swing positions of the load.

[0012] The step of calculating may include solving differential equations.

[0013] The first set of geometrical figures may comprise at least one circle with its diameter matching the corresponding side of an obstacle.

[0014] The first set of geometrical figures may comprise at least one line with its length matching the corresponding side of an obstacle.

[0015] The first set of geometrical figures may comprise at least one polygon with the length of one of its sides or a major dimension matching the corresponding side of an obstacle.

[0016] The first set of geometrical figures may comprise at least one ellipse with one of its axes matching the corresponding side of an obstacle.

[0017] A second aspect of the invention is a computer program comprising computer program code executable in a controller of a trajectory calculator, wherein the computer program code, when run in the controller, causes the trajectory calculator to perform the method according to the first aspect.

[0018] A third aspect of the invention is a computer program product comprising a computer program according to the second aspect and a computer readable means on which the computer program is stored.

[0019] A fourth aspect of the invention is a trajectory calculator for calculating a trajectory for a crane to move a load from a starting position to a destination position. The trajectory calculator comprises: a data obtainer arranged to obtain data representing obstacles restricting a path from the starting position to the destination position of the load; and a calculator module arranged to calculate a trajectory for the load to follow. The calculator module is arranged to use a two dimensional geometrical model, wherein the model comprises: a first set of geometrical figures, wherein each geometrical figure of the first set corresponds in position to a side of one of the obstacles, and a second geometrical figure representing potential positions of the load in the case of swinging, wherein the calculator module is arranged to calculate the trajectory such that the second geometrical figure avoids intersecting any of the geometrical figures of the first set.

[0020] It is to be noted that any feature of the first, second, third and/or fourth aspect are, when possible, applicable to any other aspect.

[0021] Whenever the term match is used herein, it is to be construed as being of essentially identical.

[0022] Generally, all terms used in the claims are to be interpreted according to their ordinary meaning in the technical field, unless explicitly defined otherwise herein. All references to "a/an/the element, apparatus, component, means, step, etc." are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, step, etc., unless explicitly stated otherwise. The steps of any method disclosed herein do not have to be performed in the exact order disclosed, unless explicitly stated.

BRIEF DESCRIPTION OF DRAWINGS

[0023] The invention is now described, by way of example, with reference to the accompanying drawings, in which:

Fig 1 is a schematic diagram showing a model including a trajectory for a load from a starting position to an end position when there are no obstacles,

Fig 2 is a schematic diagram showing a model including a trajectory for the load from the starting position to the end position when there are obstacles and no consideration is made for emergency stops,

Fig 3 is a schematic diagram showing a model including a trajectory for the load from the starting position to the end position when there are obstacles and consideration is made for sudden stops,

Fig 4 is a schematic drawing showing modules of a trajectory calculator capable of calculating the trajectory of Fig 3,

Fig 5 is a schematic drawing showing hardware devices of the trajectory calculator of Fig 4,

Fig 6 is a schematic drawing showing one example of a computer program product comprising computer readable means; and

Fig 7 is a flow chart illustrating calculation of trajectory according to one embodiment.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0024] The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which certain embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided by way of example so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout the description.

[0025] Fig 1 is a schematic diagram showing a model including a trajectory 20 for a load 12 from a starting position 11a to an end position 11b when there are no obstacles. The load 12 is controlled from a crane comprising a trolley 10 and a cable 13. The height of the load 12 in the y direction 12 compared to the trolley 10 can be adjusted by hoisting. Moreover, the trolley 10 can move along the x direction. In this example, there are no obstacles, so the calculation of the trajectory is as simple as hoisting the load 12 sufficiently to clear the ground, moving the trolley 10 and lowering the load 12 to the end position 11b.

[0026] Fig 2 is a schematic diagram showing a model including a trajectory 21 for the load 12 from the starting position 11a to the end position 11b when there are obstacles 15a-e and no consideration is made for emergency stops. The obstacles 15a-e can be any obstacle which needs to be cleared by the load 12 in its movement. For example, the obstacles 15a-e can be shipping containers. In this trajectory 21, the obstacles 15a-e are only just passed in the movement of the load 12, as illustrated by the dashed lines of the trajectory 21. In one way, this trajectory 21 is an optimal route since there is no superfluous and slow hoisting to clear the obstacles 15a-e.

[0027] However, consider the midway position 11c of the load 12. While in movement, the cable 13' is at an angle due to acceleration and movement of the trolley 10 along the x-axis. If the trolley 10 at this point would have to make an emergency stop, the load 12 would swing from position 11c into the obstacle 15a. It is thus desirable to have some margin between the load and the obstacles to avoid the load 12 from swinging into obstacles 15a-e in the case of a sudden stop. However, the margin should not be too large, as this would result in unnecessary and slow hoisting.

[0028] Fig 3 is a schematic diagram showing a model including a trajectory 22 for the load 12 from the starting position 11a to the end position 11b when there are obstacles 15a-e and consideration is made for sudden stops. In this model, a set of geometrical figures 30a, 30b, 30c, 30e are generated, wherein each geometrical figure 30a, 30b, 30c, 30e corresponds in position to a side 17a, 17b, 17c, 17e of one of the obstacles 15a-e. The sides 17a, 17b, 17c, 17e are all external sides which could potentially be interfaces of collision for the load. Optionally, geometric figures are also provided for other external surfaces such as top surfaces (not shown). The geometrical figures can be circles, ellipses, lines, rectangles, etc, as long as the sides of the obstacles are encompassed.

[0029] Moreover, a second geometrical figure 31 representing potential positions of the load 12 in the case of swinging is generated. In this example, the second geometrical figure 31 is a circle, but any suitable geometrical figure can be selected as long as it encompasses the potential maximal swinging position of the load 12. This is explained in more detail with reference to Figs 8a-c.

[0030] In this example, the trajectory is calculated such that the second geometrical figure 31 avoids intersecting any of the geometrical figures 30a, 30b, 30c, 30e of the set. Consider midway position 11d. If the trolley were to suddenly stop, e.g. due to an emergency stop or power failure, due to the built in margins of the calculated trajectory 22, the load 12 will not swing into the obstacles 15a-e.

[0031] Fig 8a is a schematic illustration of when swinging is considered when calculating the trajectory. For each position in the trajectory, the angle α denotes an angle from the normal of the trolley when the load is in a particular position 11c. α can be calculated as a function of a number of variables, e.g. previous acceleration in the x direction and previous acceleration in the y direction, cable length, etc. Based on the position of the load 11c, an opposite swing position 11e is calculated. The worst case scenario in the case of a sudden stop is that the load swings all the way to a position 11e, defined as the opposite side of the normal, at the angle α' = a away from the normal. However, α', can be calculated as an angle smaller than α, taking into account friction, etc. The second geometrical figure 31 is positioned based on the calculated opposite swing position, e.g. centred about the load in this position 11e. The trajectory is thus calculated such that the second geometrical figure 31 avoids intersecting the geometrical figures, here 30c, of the obstacles, here 15b throughout the trajectory.

[0032] Fig 8b is a schematic illustration a potential extreme case of swinging. If, as explained with reference to Fig 8a, the trajectory is calculated only at the opposite swing position 11e, there may exist, when α is large, a situation where obstacles 15a-b are situated between the actual position and the opposite swing position lie. Due to the large angle α, the second geometrical figure 31 does not intersect any of the geometrical figures of the obstacles. However, it is clear that if there were to be a sudden stop when the load is in position 11c, the load would swing into the obstacles 15a-b. Fig 8c is a schematic illustration of a solution to the potential extreme case of swinging of Fig 8b. Here, there is not only one second geometrical figure representing the swing position, but a set of second geometrical figures 31a-d. The set of second geometrical figures 31a-d can for example be determined such that they together cover an arc 32 between the position 11c of the load 12 and the opposite swing position 11e. Alternatively, all positions between the position 11c of the load 12 and the opposite swing position 11e are considered. In any case, the trajectory is determined such that the whole set of second geometrical figures 31a-d avoid intersecting the geometrical figures of the obstacles.

[0033] Fig 4 is a schematic drawing showing modules 40, 42 of a trajectory calculator 1 capable of calculating the trajectory of Fig 3. The modules 40, 42 can be implemented using hardware and/or software of the trajectory calculator 1.

[0034] A data obtainer 40 is arranged to obtain data representing obstacles restricting a path from the starting position to the destination position of the load.

[0035] A calculator module 42 is arranged to calculate a trajectory for the load to follow as was explained with reference to Fig 3.

[0036] Fig 5 is a schematic drawing showing hardware devices of the trajectory calculator 1 of Fig 4,

[0037] A controller 44 is provided using any suitable central processing unit (CPU), microcontroller, digital signal processor (DSP), etc., capable of executing software instructions stored in a computer program product or memory 46. The memory 46 can be any combination of read and write memory (RAM) and read only memory (ROM). The memory also comprises persistent storage, which, for example, can be any single one or combination of magnetic memory, optical memory, or solid state memory or even remotely mounted memory.

[0038] An input/output (I/O) interface 47 is provided to allow the trajectory calculator 1 to interact with other components, such as the crane 50. The I/O interface 47 can for example be a network interface such as an Ethernet interface.

[0039] Fig 6 shows one example of a computer program product 70 comprising computer readable means. On this computer readable means a computer program 71 can be stored, which computer program can cause a controller to execute a method according to embodiments described herein. In this example, the computer program product is an optical disc, such as a CD (compact disc) or a DVD (digital versatile disc) or a Blu-Ray disc. As explained above, the computer program product could also be embodied as a memory of a device, such as memory 46 of the trajectory calculator 1. While the computer program 71 is here schematically shown as a track on the depicted optical disk, the computer program can be stored in any way which is suitable for the computer program product.

[0040] Fig 7 is a flow chart illustrating calculation of trajectory according to the embodiment illustrated in Fig 3.

[0041] In an initial obtain data step 60, the model is built, e.g. by obtaining data for obstacles to avoid.

[0042] In a calculate trajectory step 62, the trajectory is calculated as is explained with reference to Fig 3 above. The trajectory can be calculated using the model to obtain, under the conditions given, an optimal trajectory path, e.g. using differential equations.

[0043] In a send movement signals step 64, the calculated trajectory is sent to the crane to be effected.

[0044] The invention has mainly been described above with reference to a few embodiments. However, as is readily appreciated by a person skilled in the art, other embodiments than the ones disclosed above are equally possible within the scope of the invention, as defined by the appended patent claims.

Claims

1. A method of calculating a trajectory for a crane (50) to move a load (12) from a starting position (11a) to a destination position (11b) comprising the steps of:

   obtaining (60) data representing obstacles (15a-e) restricting a path from the starting position to the destination position of the load; and
   calculating (62) a trajectory (22) for the load to follow,
   characterised in that the step of calculating includes the use of a two dimensional geometrical model (5), wherein the model comprises:

      a first set of geometrical figures (30a, 30b, 30c, 30e), wherein each geometrical figure of the first set corresponds in position to a side (17a, 17b, 17c, 17e) of one of the obstacles (15a-e), and
      a second geometrical figure (31) representing potential positions of the load in the case of swinging,
      wherein the trajectory is calculated such that the second geometrical figure avoids intersecting any of the geometrical figures of the first set.

2. The method according to claim 1, wherein the second geometrical figure is fixed to a calculated opposite swing position (11e) of the load for a plurality of potential load positions of the trajectory, wherein the plurality of potential load positions are for a plurality points in time.

3. The method according to claim 1 or 2, wherein any side (17a, 17b, 17c, 17e) of the obstacles corresponds to at most one geometrical figure (30a, 30b, 30c, 30e) of the first set.

4. The method according to any one of the preceding claims, further comprising the step (64) of sending signals to effect movement of the crane according to the calculated trajectory.

5. The method according to any one of the preceding claims, wherein the second geometrical figure (31) is a circle containing potential swing positions of the load.

6. The method according to any one of the preceding claims, wherein the step of calculating includes solving differential equations.

7. The method according to any one of the preceding claims, wherein the first set of geometrical figures comprises at least one circle with its diameter matching the corresponding side of an obstacle.

8. The method according to any one of the preceding claims, wherein the first set of geometrical figures comprises at least one line with its length matching the corresponding side of an obstacle.

9. The method according to any one of the preceding claims, wherein the first set of geometrical figures comprises at least one polygon with the length of one of its sides or a major dimension matching the corresponding side of an obstacle.

10. The method according to any one of the preceding claims, wherein the first set of geometrical figures comprises at least one ellipse with one of its axes matching the corresponding side of an obstacle.

11. A computer program (71) comprising computer program code executable in a controller (44) of a trajectory calculator (1), wherein the computer program code, when run in the controller, causes the trajectory calculator to perform the method according to any one of claims 1 to 10.

12. A computer program product (70) comprising a computer program according to claim 11 and a computer readable means on which the computer program is stored.

13. A trajectory calculator for calculating a trajectory for a crane to move a load from a starting position to a destination position, the trajectory calculator comprising:

   a data obtainer (40) arranged to obtain data representing obstacles restricting a path from the starting position to the destination position of the load; and
   a calculator module (42) arranged to calculate a trajectory for the load to follow,

   characterised in that the calculator module is arranged to use a two dimensional geometrical model, wherein the model comprises:

   a first set of geometrical figures, wherein each geometrical figure of the first set corresponds in position to a side of one of the obstacles, and
   a second geometrical figure representing potential positions of the load in the case of swinging,
   wherein the calculator module is arranged to calculate the trajectory such that the second geometrical figure avoids intersecting any of the geometrical figures of the first set.

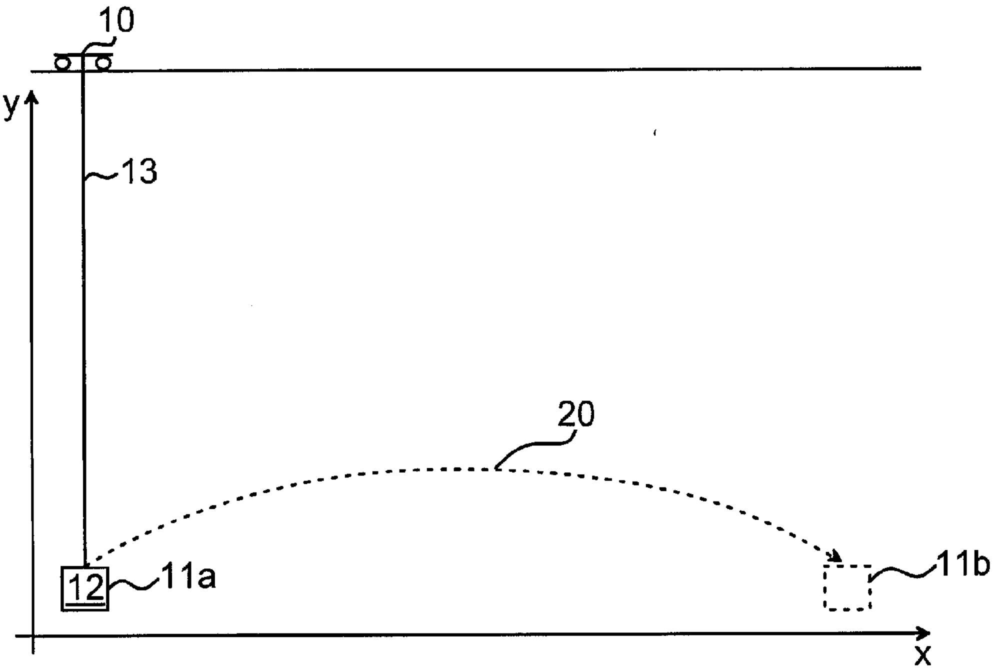

Fig. 1

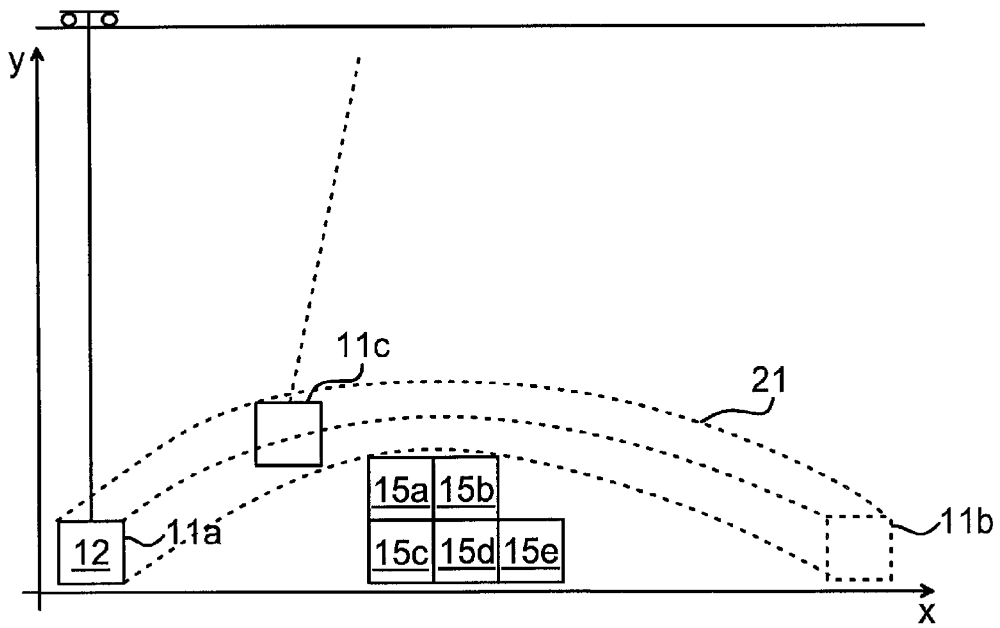

Fig. 2

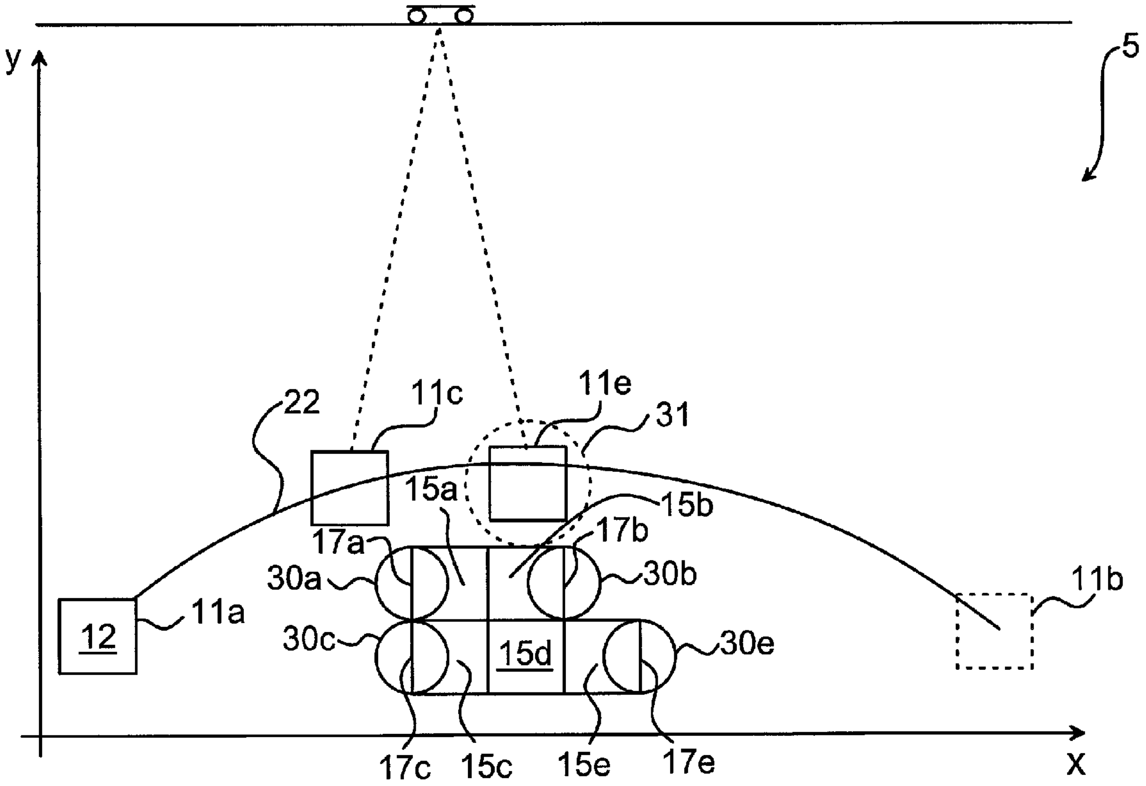

Fig. 3

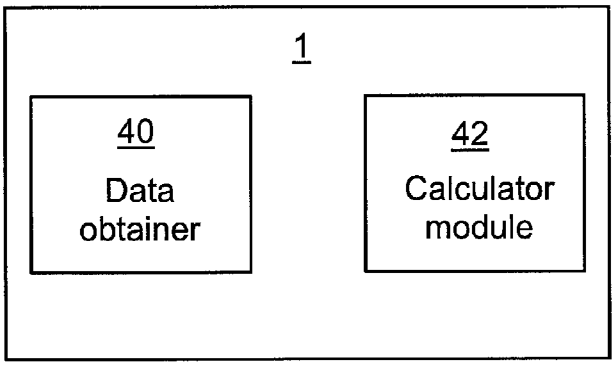

Fig. 4

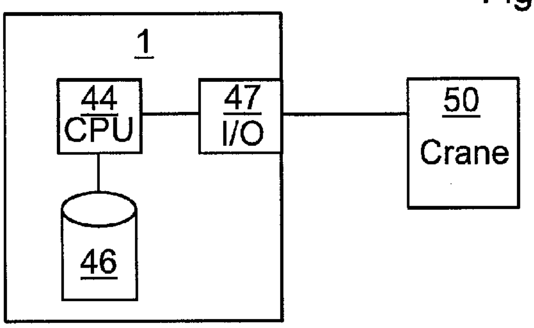

Fig. 5

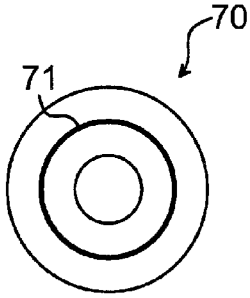

Fig. 6

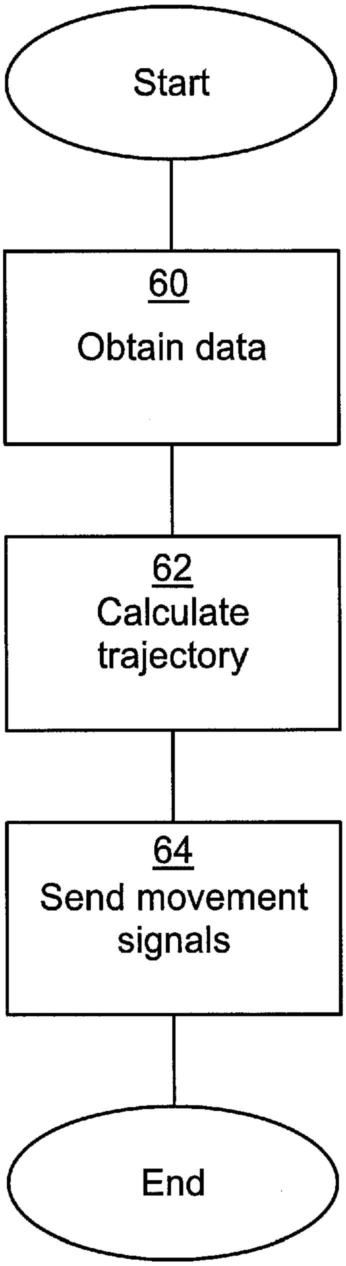
Start
60
Obtain data
62
Calculate trajectory
64
Send movement signals
End

Fig. 7

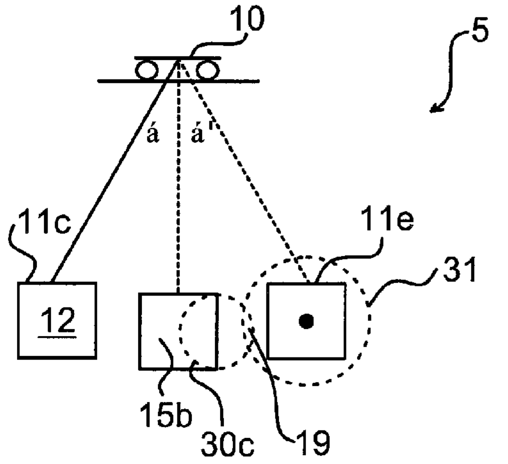

Fig. 8a

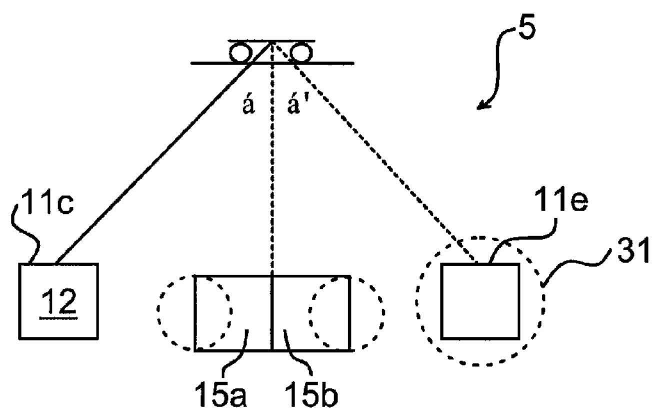

Fig. 8b

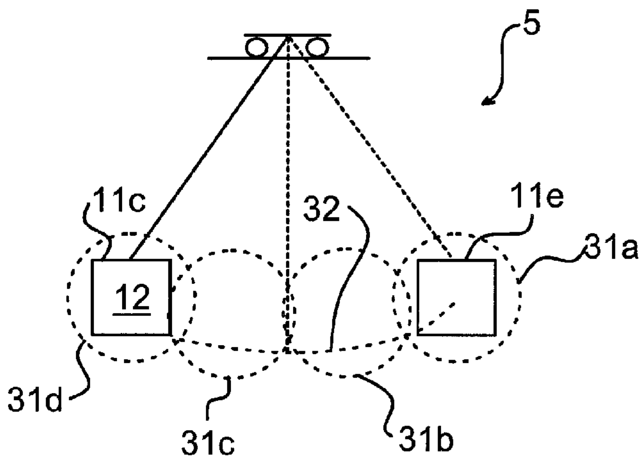

Fig. 8c

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EUROPEAN SEARCH REPORT

Application Number
EP 10 16 7938

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	30 November 2010	Sheppard, Bruce

CATEGORY OF CITED DOCUMENTS

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