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COMPUTER CONTROLLED METHOD AND APPARATUS FOR FAIRING AND
PAINTING OF MARINE VESSEL SURFACES

The present invention generally relates to
5 automated fairing and painting of marine vessels, and the
present invention specifically relates to the use of
computer controlled robotic equipment for analyzing surface
imperfections, fairing, applying a sprayable fairing
compound, and painting.

10 Custom marine vessels are constructed today using
time proven techniques and methods. Part of this process is
known as fairing. Fairing is a process whereby a less than
smooth surface is filled, sanded and primed in preparation
for painting. Fairing, as applied in the marine industry,
15 is done almost exclusively on the exteriors of yachts,
where the greatly enhanced aesthetic quality of paint on a
professionally faired hull or superstructure imparts a
uniform mirror like quality to the paint finish. Commercial
or military marine vessels are almost never faired due to
20 the cost and time involved as well as the purely aesthetic
nature of such a process.

Fairing is accomplished by analyzing a marine
vessel's exterior surface for imperfections and then
utilizing certain techniques for removing the imperfections
25 from the hull or superstructure. Traditionally, a crew of
skilled craftsmen using hand operated air tools, hand
operated electric tools, simple hand tools or any
combination thereof has performed this process. The first
step is to analyze the imperfections in the hull or
30 superstructure surface by using a straight edged, elongated
board or batten to "map" or mark imperfections in the
vessel surface. The next step involves applying a primer,
usually a spray applied primer. After the "mapping" and
priming steps, any imperfections greater than approximately
35 1/8" (3 mm) in depth are manually filled with trowelable fairing

compound, applied using hand trowels and long metal spreaders. When the troweled filler has cured, it is hand sanded using hand blocks and "longboards" with sandpaper attached and with manually operated power sanders. When the
5 surface being faired is relatively smooth and fair, a final optional application of sprayable fairing compound may be applied using manually operated spray equipment. Once all of the fairing compound has been applied and manually sanded, priming and painting the faired hull or
10 superstructure then completes the fairing and painting process.

Using current methods, a surface with 5,000 square feet (500 m^2) of fairable area takes approximately 2.2 man-hours per square foot ($24 \text{ man-hours per m}^2$) or 11,000 total man-hours to fair from an
15 unfaired surface to a high quality, i.e. "yacht quality", painted finish. Related industries, such as the automobile manufacturing industry, have attempted to solve the inefficiency corresponding to large tasks performed by hand, by automating certain aspects of production. For
20 example, U.S. Patent No. 4,532,148, to Veciello, describes an automated painting system for automobiles performed primarily by robots with rotary bell-type atomizing devices attached to the robot arm. While this invention is adequate for painting mass-production automobiles, it only serves to
25 paint.

U.S. Patent No. 4,498,414, to Kiba, et al., describes an automobile painting robot. This robot was designed to paint automobiles on an assembly line with the additional feature of being able to open the car door for
30 greater access for painting.

While the above patents relate to automated painting robots and a system for painting with robots, U.S. Patent No. 5,571,312, to Andoe, describes a coating material that could be applied by the robots to a marine
35 vessel.

None of the above references, each of which is incorporated herein by reference, describe a method for fairing a marine vessel. In addition, the marine vessel industry has not devised an automated method to save the
5 time and expense expended in fairing a vessel hull and superstructure.

As a consequence, there is a need in the art for a method of automated fairing of marine vessels in order to save time and expense, and to ensure precision fairing.

10 There is a further need in the art for a method of automated fairing that employs multi-function robots with interchangeable operative heads.

The present invention satisfies the needs in the art by providing automation technology to analyze, fair and
15 paint the hulls and superstructures of marine vessels in order to save material cost, labor and to provide computer-controlled precision fairing.

The preferred embodiment of the invention is a computer-implemented method for fairing the hull or
20 superstructure of a marine vessel, utilizing a robot system which includes multiple robots positioned on moveable means and having arms provided with various attachments, moveable about various control axes, comprising the steps of positioning the marine vessel so as to provide the robots
25 access to the hull and superstructure; analyzing the vessel's hull and superstructure for imperfections; applying a fairing compound to the imperfections; sanding the fairing compound in alignment with the hull or superstructure; removing any compound dust generated by the
30 sanding process; and priming and painting the hull or superstructure.

In another preferred embodiment the robots are positioned on glide tracks or a gantry for movement.

In another preferred embodiment the robots are provided with arms adaptable for affixing and using various attachments.

5 In another preferred embodiment the analyzing step further comprises using a surface mapping system utilizing lasers, affixed to the robot.

In another preferred embodiment the analyzing step further comprises using a surface mapping system utilizing radar, affixed to the robot.

10 In another preferred embodiment the fairing compound application step further comprises using a spraying apparatus; affixed to the end of the robot arm.

In another preferred embodiment the fairing step further comprises using a milling apparatus and vacuum
15 apparatus in conjunction with one another, affixed to the end of the robot arm.

In another preferred embodiment the painting step further comprises using a second spraying apparatus, affixed to the end of the robot arm.

20 In another preferred embodiment the steps further comprise using interchangeable attachments for use by the robots.

Accordingly, it is an object of the invention to use robots to analyze the imperfections in a marine
25 vessel's hull or superstructure by utilizing a surface mapping laser or radar.

It is a further object of the invention to use robots to apply any sprayable fairing compound as may be necessary to correct the detected imperfections in a marine
30 vessel's hull or superstructure by utilizing spraying equipment to apply the compound.

Another object of the invention is to use robots to sand the fairing compound once it has been applied to the vessel in order to achieve a smooth surface by use of a milling or sanding head.

5 A still further object of the invention is to remove, from the work area, the fairing compound dust created by the sanding process by a vacuum tube or other similar cleaning means.

10 A still further object of the invention is to use robots to apply the final paint coat to the vessel surface by utilizing spraying equipment to apply the paint.

15 A still further object is to provide moveable means for the robots for the purpose of allowing the robots complete access to the vessel's hull and superstructure surfaces.

Another object of the invention is to provide the robots with interchangeable heads for accomplishing the tasks of analyzing the hull for imperfections, applying fairing compound, sanding the hull and painting.

20 The above objects and advantages of the present invention will become apparent from the following description and appended claims, taken in conjunction with the accompanying drawings which show by way of example some preferred embodiments of the invention.

25 Fig. 1 is a plan view of a vessel located in the operational area of the automated fairing system and approximate layout of said system according to the present invention;

30 Fig. 2 is a perspective view of the automated fairing system including a gantry mounted robot, according to a preferred embodiment;

Fig. 3 is an elevational side view illustrating a track mounted fairing robot and gantry mounted robot as

utilized in the automated fairing system and method according to the present invention; and

Figs. 4A-4D are perspective views of the various heads to be used in conjunction with the robots according to the present invention.

Referring to the drawings, and more particularly Fig. 1 thereof, an automated fairing system 10 is shown which includes a controller 12 for directing the movement of robots 14. Said controller is capable of receiving various electrical input signals for initiating the operation of the robots 14 in accordance with a preprogrammed sequence of operation. The robots 14 are located on parallel tracks 16 for movement along the longitudinal axis of the marine vessel 18. The vessel 18 is situated in the operational area of the robots 14, between the tracks 16, allowing said robots complete access along the length of the vessel 18.

Fig. 2 represents a perspective view of an alternative embodiment of the system 10, in which the robots 14 on tracks 16 can be seen working on the vessel 18 in conjunction with a gantry 20 and gantry mounted robot 22, said gantry 20 and gantry mounted robot 22 are also controlled by the controller 12. According to the alternative embodiment, the gantry 20 would have the capability of linear movement 24 up and down the longitudinal axis of the vessel 18 and the robot 22 on the gantry 20 would have side to side movement and telescoping means 35 to raise or lower to the work surface.

As stated in the description of Fig. 1, this invention operates with, and the apparatus thereof includes, robots 14 (Fig. 1), without a gantry 20. Additionally, when using gantry 20, various alternative structures are operative within the bounds of this invention, such as when the "legs", as are shown in Fig. 2, or with "legs" as shown but suspending the gantry from above.

As can be seen in Fig. 3, the robots, 14 and 22, are hydraulically operated units which include a base 30, a primary arm 32, a secondary arm 34 and a wrist 36 that terminates in a support head 38, which interlocks with any one of the interchangeable tools 50, 60, 70 and 80. The controller 12 and the base 30, the primary arm 32, the secondary arm 34, the wrist 36, the support head 38 and the interchangeable tools 50, 60, 70 and 80 are operatively connected for achieving the end result of movement of the interchangeable tools 50, 60, 70, and 80 in a desired manner.

Figs. 4A-4D illustrate the various interchangeable tools 50, 60, 70, and 80 as utilized in the automated fairing system 10. The optional analyzer tool 50 in Fig. 4A is used for analyzing the vessel's surface 19, through the use of surface mapping laser or radar 53. This tool is affixed using a connective means 51 which interlocks with wrist 36. The analyzing process may be accomplished with the analyzing means attached to the base 30 of the robots 14 and 22 rather than at the end of the secondary arm 34.

The fairing compound application tool 60 in Fig. 4B, employs a spray nozzle 62 supplied with compressed air 64 and fairing compound 66 through hoses 65 and 67 respectively. The tool is affixed using a connective means 61 that interlocks with the wrist 36.

Fig. 4C portrays an interchangeable sanding tool 70 useable for sanding the areas treated with fairing compound 66. The tool uses a means for sanding 72 in conjunction with a vacuum hose 74 for the removal of the toxic dust created from smoothing the fairing compound 66. A hood 76 encloses the sanding means 72 and the vacuum hose 74, the vacuum hose projecting through the tool 70 and within the hood 76, proximate sanding means 72, which is not shown in the drawing of Fig. 4C for the sake of clarity, but is to be understood that way, as previously described herein. The hood 76 is used to prevent the dust from escaping and is

also used to enhance the suction capability of the vacuum 74. The sanding tool 70 is interchangeably affixed to the wrist 36 by a connective means 71. Also, usable for cleaning the surfaces, analyzed and treated with fairing compound 66, are various alternative means; e.g. a water-blasting means is used in one of the tools, but this requires sufficient connections for handling water, and this potentially requires a drying means for use after the water-blasting or power-washing. When water-blasting is used for cleaning, the pressure is adjusted for the size of the vessel (less for a yacht, than for a large ship). Furthermore, particularly with large ships, the present invention method involves only the steps of positioning the vessel, cleaning with water-blasting, and analyzing for imperfections or contours before repairing and/or painting.

An interchangeable painting tool 80 is shown in Fig. 4D, a perspective view. Paint 86 is applied through a spray nozzle 82 that is supplied by hoses 85 and 87 with compressed air 84 and paint 86 respectively. The painting tool 80 is interchangeably affixed to the wrist 36 by a connective means 81.

It will be understood that the preferred embodiments of the present invention has been disclosed by way of example and that other modifications and alterations may occur to those skilled in the art without departing from the scope and spirit of the appended claims.

CLAIMS

1. A computer-implemented method for fairing and painting the hull and/or superstructure of a marine vessel, utilising a robot system which includes multiple robots positioned on moveable means and having arms provided with various attachments, moveable about various control axes, comprising the steps of:
 - (a) positioning said marine vessel so as to provide said robots access to said hull and superstructure;
 - (b) analysing said vessel's hull and superstructure for imperfections;
 - (c) applying a fairing compound to said imperfections;
 - (d) sanding said fairing compound in alignment with said hull and/or superstructure;
 - (e) removing any compound dust generated by the sanding process; and
 - (f) painting said hull and/or superstructure.
2. The method of claim 1, wherein said robots are positioned on glide tracks or a gantry for movement.
3. The method of claim 1 or 2, wherein said robots are provided with arms adaptable for affixing and using various attachments.
4. The method of claim 1, 2 or 3, wherein said analysing step further comprises use of a surface mapping system utilising lasers, affixed to the robot.
5. The method of any one of the preceding claims, wherein said analysing step further comprises use of a surface mapping system utilising radar, affixed to the robot.
6. The method of any one of the preceding claims, wherein said fairing compound application step further comprises use of a spraying apparatus, affixed to the end of said arm.

7. The method of any one of the preceding claims, wherein said fairing step further comprises use of a grinding, milling or sanding apparatus which operate in conjunction with one another and which are affixed to the end of said arm.
8. The method of any one of the preceding claims, wherein said painting step further comprises a second spraying apparatus, affixed to the end of said arm.
9. A computer-controlled method for finishing at least the hull of a marine vessel, involving a computer for directing the movement of robots, said robots positioned on moveable means, such as a gantry, tracks and/or a gantry-track combination, each of said robots having a base, a primary arm, a secondary arm and a wrist terminating in a support head, and various tools attachable to said wrists or said bases, the method comprising the steps of:
 - (a) positioning said marine vessel, relative to said robots, so that said robots are operatively accessible to surfaces defined by said marine vessel;
 - (b) attaching and using an analyser tool on each of said robots for analysing the surfaces of said marine vessel to detect contours and imperfections;
 - (c) attaching and using a surface sensing tool on each of said robots for preparing said surfaces for painting; and
 - (d) attaching and using a painting tool on each of said robots for painting said surfaces.
10. The method of claim 9, wherein said analysing step further includes the production of a surface map by the use of lasers attached to said robots.
11. The method of claim 9 or 10, wherein said analysing step further includes the production of a surface map by the use of a radar system attached to said robots.
12. The method of claim 9, 10 or 11, wherein, after said positioning step, a water-blasting tool is attached to each of said robots, and used to clean said surfaces.

13. The method of any one of claims 9 to 12, wherein after said analyser step, a fairing compound application tool is attached to each of said robots and used to apply a fairing compound to said imperfections.
14. The method of any one of claims 9 to 13, wherein said fairing compound application step further comprises the use of spraying apparatus attached to said robots.
15. A computer controlled apparatus for finishing vessel surfaces and painting of the hull and superstructure surfaces of a marine vessel having a hull, comprising a plurality of robots, controllable by said computer, mounted on means moveable relative to said marine vessel, a plurality of tools attachable to said robots for mapping the surface contours of said vessel, and for painting said surfaces.
16. The apparatus according to claim 15, wherein tools are provided for applying a fairing compound to said surfaces where imperfections are found and tools are provided for sanding said surfaces to prepare them for painting.
17. The apparatus according to claim 15 or 16, wherein said apparatus comprises a pair of tracks, each track arranged with one track on each side of said hull, and a pair of robots, each robot moveable along one of said tracks.
18. The apparatus according to any one of claims 15 to 17, wherein one of said tools comprises a means for sanding to prepare said surfaces for painting.
19. The apparatus according to any one of claims 15 to 18, wherein one of said tools comprises a means for water-blasting to clean said surfaces.
20. Apparatus comprising control means, multiple robots and means on which said robots are moveable, operable according to the method of any one of claims 1 to 14.