THE SIRIUS ROBOT PLATFORM FOR TOOL HANDLING ON LARGE VERTICAL SURFACES

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Abstract: Recent technological developments have promoted robots beyond tasks associated solely with factory automation. The Fraunhofer Institute of Factory Operation and Automation (IFF) has developed a modular robotic platform called SIRIUS for the dull and dangerous processes associated with work on large vertical surfaces. Its design features are described and its utilization as a facade cleaning robot show its applicability.

Keywords: service robot, climbing robot, tool handling, stride control, facade cleaning, maintenance, vertical surfaces

1 INTRODUCTION

Now that robots have revolutionized industrial serial production, they are beginning to be used in even more complex applications, both inside and outside the factory setting. The variety of these applications is currently limited to monotonous, unfriendly and/or dangerous tasks.

Compared to other areas, vertical surfaces lend themselves easily to the deployment of a robot. They are relatively automation friendly, that is isolated from extraneous influences, the work space is well defined and regularly structured, while manual work at great heights can be quite dangerous.

Thus a large number of recurring operations on vertical surfaces will easily call for automation. Developing a robotic platform for precise movement on a vertical surface and handling complex tools for specific tasks is a logical first step in the introduction of automation to in any new field of application.

2 SYSTEM DESIGN

2.1 Main objectives

The aim of the development was a kinematic system which can be used on a multitude of vertical planar surfaces to carry any complex tool for a many diverse applications. The following general conditions for the robot system were formulated:

- fully and semiautomatic movement
- applicable to the greatest possible number of vertical surfaces
- ability to maneuver over obstacles
- easy integration of different tools (modularity)
- supporting cables for safety reasons
- permanent contact to the surface
- quick but exact movement
- continuous and discontinuous movement
- correction of the direction of motion
- main movement in vertical direction
- indirect horizontal motion

The points of emphasis for the development of a modular robot system on different vertical surfaces were:

- safety devices
- kinematics
- control and sensing, navigation
- power and media supply
- integration of tool kit modules

2.2 Modular concept

The modularity of the SIRIUS enables handling of different tools and maneuverability on many surfaces. It can also integrate different sensors for specific tasks. The robot can easily adapt to changes in the type of vertical surface by simply exchanging few elements of the kinematics such as different vacuum cups or longer actuators.

Since the tools are handled automatically and are modular, they can be more complex and result in a higher and constant quality, thus supporting arguments for implementation discussion.

Examples of potential applications include

- Cleaning
- Inspection work
- Coating
- Welding

Its climbing abilities can be used in a variety of areas, e.g.

- ship yards
- construction sites
- maintenance of dams
- on facades (windows) of high-rise buildings

2.3 Advantages

As previously stated, automatic operation of complex tools with a climbing robot has several particular advantages over manual work:

- constant and high quality
- reproducibility
- increase in safety

2.4 Safety first

A combination of supporting cables and suction cups allows for a high tool weight and enough adhesion force to stay safely fixed to the surface. This way the robot and tool design are less restrained in weight and force considerations. Installation of scaffolds or guide rails covering the vertical surface to adhere the robot and to assure path abidance is not necessary.

Suction cups are the most appropriate solution to generate safe contact to the object’s surface. They make the robot more independent of the surface material than magnetic wheels and other designs, while providing the most friction against shearing.

Supporting cables are indispensable to secure the system and comply with safety regulations and standards.

2.5 Kinematic concept

The kinematic concept attempts to accomplish three goals: to guarantee permanent contact between the robot and the surface, to overcome a multiplicity of typical obstacles and to move quickly along the facade. The generation of a sufficient amount of contact force to counter the induced reaction forces as well as wind forces are particularly considered.

The kinematics are based on a structure of two pairs of linear modules each outfitted with several vacuum cups. The length of the module and the number of vacuum cups are parameters of the system dependent on the surface structure. Pneumatic cylinders supply an additional degree of freedom by enabling movement of the individual cups perpendicular to the surface.

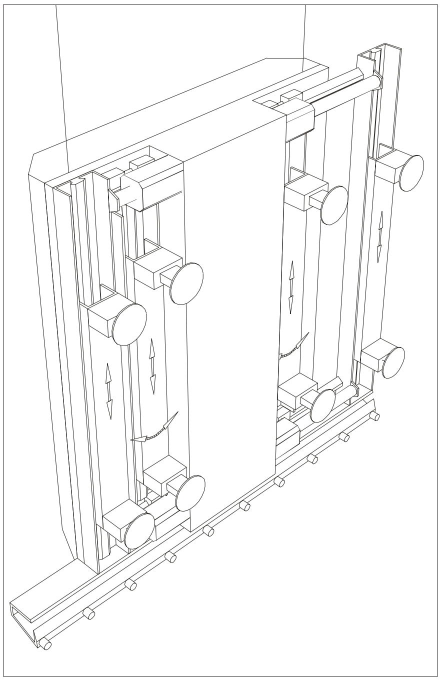

Figure 1: Modular robot system

The four linear modules function in pairs of two which guarantees safe and stable contact. The two pairs interact to allow for the system to move continuously along a vertical axis.

Because the robot's weight is carried by the cables, its load upon the surface is small. The vertical movement along the surface is produced only by the cable stroke, while the linear modules in contact with the surface are used like temporary guide rails. The cable stroke can be actuated by a trolley from above or by a hoist located directly on the robot.

2.6 Overcoming obstacles

Obstacles affect the following system parameters:

- length of the linear module
- module stroke length
- number, size, and location of vacuum cups

The length of the pneumatic cylinders depends upon the height of the obstacles perpendicular to the surface, such as sun-blinds, framework, etc. Sensors detect the obstacles and the system automatically generates an appropriate foot stepping sequence. Only the vacuum cups which are not over the obstacle are extended. The arrangement of the vacuum cups, therefore, must be adapted according to the construction of the surface. This also affects the minimum length of the linear modules and their stroke. The vacuum cup diameter depends on the roughness of the surface to ensure establishment of a vacuum.

3 CONTROL TECHNIQUES

The entire control system is located on the robot. It controls position and stride, operates the mounted tool and incorporates the man-machine interface commands.

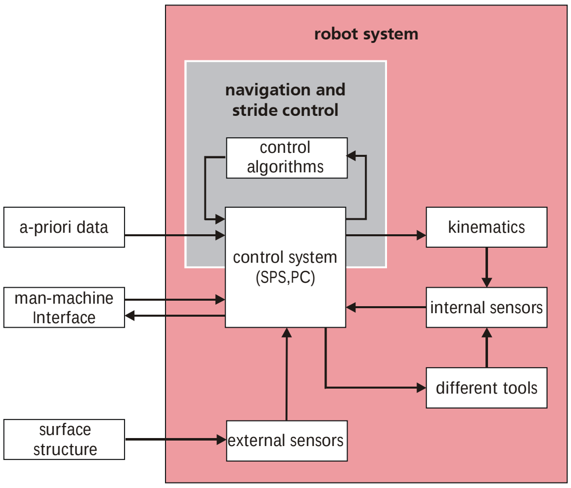

Figure 3: System structure

3.1 Navigation and stride control

Knowledge about the surface layout is necessary in order to first generate robot movement. Usually this takes place via simple inputs and as a part of the installation of the equipment. This initialization data contains “off” positions, moving distances, and path characteristics. It is supplemented by external sensors which acquire the actual surface features. The deviation of the robot from its ideal line is detected by sensors sensing beams in the construction, seals on the glass, or with an attitude sensor.

External sensors provide information about obstacles to help generate an appropriate stride. An intelligent foot stepping sequence guarantees maximum foothold.

3.2 Control of a mounted tool

Depending on the installed tool, its control is performed either directly via the robot control or by a simple signal exchange with an extra tool control.

3.3 Man-Machine interface

For interaction with the operator, all relevant data is passed to a control device. The control device is only used for visualization of system status and the start and stop commands of robot action. All other control functions (the error control etc.) are implemented on board and are automatically executed via robotic control.

The connection between the robot and the control device is established via a bus system. The kind of the control device is freely selectable; operation is possible by using a simple operator panel or modern means such as a cell phone or avatar-like operation over the web.

4 FACADE CLEANING

Due to the simple exchange of the gondola and adaptation of the roof carriage, facade cleaning was a natural fit for the first implementation of the robot. Furthermore, the cleaning of glass facades is a relatively simple but dangerous and dull job.

SIRIUS$_C$ was thus developed, a synthesis of the modular robot climbing platform SIRIUS and the cleaning tool SKYWIPEplus of Dornier Technology.

4.1 Modular concept

The tool incorporates a cleaning head limited to horizontal movement along a linear axis, which is mounted to the bottom of the platform. The elastically supported head uses rotating brushes and water to clean the windows. The rinsing water is reabsorbed around the brushes, filtered and returned to the on-board water storage.

Infrared sensors are used to detect obstacles within the facade structure, so as to be able to generate an optimal stride.

Figure 4: SIRIUS$_C$

4.2 Work procedure

The robot can either be stored on the trolley on top of the roof or in a garage and attached to the trolley cables on the ground for utilization. After refilling the water storage, the robot is put on the facade in the starting position of the cleaning procedure. Cleaning of a column begins at the top and moves downwards a set number of meters. In the next step, SIRIUS_C walks back up, cleaning the panes in range of the linear axis below the robot. That way, the vacuum cups leave no tracks on the glass. The robot is then moved sideways on the trolley and begins the process anew in the next column of the facade. The robot cleans up to 75m²/hr, including the time it takes to move the robot down and sideways on the facade.

4.3 Advantages

Apart from the previously stated reasons, using the Sirius for building maintenance tasks like facade cleaning also provides

- flexible operation hours due to the full automation
- outstanding cleaning performance
- low water wastage (environmentally friendly)
- privacy protection
- nurture of prestige
- preservation of the facade condition
- minimal recurring costs

5 CONCLUSION

SIRIUS_C marks the first milestone of introducing the robot platform Sirius for use on large vertical surfaces. The experiences and success gained from the robot is driving further expansion towards other applications.

At this time the abilities of SIRIUS_C are being extended towards the cleaning of materials besides glass. Furthermore, steps are being taken for a project to use the robot platform for the inspection, measurement and maintenance of facades of concrete slabs.

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