A Technological Survey on Wall Climbing Robot

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Abstract— Tall buildings and hazardous utilities require regular inspection and maintenance to comply with the ordinance, and to ensure the integrity and safety. The traditional manual inspection and maintenance on tall building normally requires the installation of expensive scaffoldings or gondolas in which human operators need to work in mid-air and life threatening environment. The prospect of climbing robots is popular because they can take the place of humans to carry out hazardous and maintenance job such as cleaning glass surfaces of skyscrapers, fire rescue, and inspection of pipes and wall, cleaning & inspection of high rise buildings, evaluation and diagnosis of a storage tank in nuclear power plants & petrochemical plants, maintenance of ship, aircraft wing inspection with the consideration of operational efficiency, safety and human health. These types of climbing robots are classified in to different groups based on their locomotion and adhesion mechanism. Due to the ability to relieve human beings from these hazardous works, more & more people are interested in developing various service climbing robots in recent years.

Keywords : Climbing Robot, Locomotion, Adhesion

I. INTRODUCTION

Inspection, maintenance and cleaning operations of civil infrastructures, such as: bridges, buildings skeletons, complex roofs, offshore platforms, etc., are very important tasks. Similar operations can be performed in the high-rise steel-based building's skeleton during its erection where all the beams joints must be tested. Every year, there are thousands of workers' accidents occurs in construction sites, which are about 25% of the total ones. Fig.1 shows main areas of inspection applications' [1], [2].

Fig.1 Climbing Environments: (A) Steel-Based Bridge, (B) Building Steel Skeleton, (C) Manual Inspection.

The periodical inspection, maintenance and cleaning of these infrastructures involve a high number of dangerous manual operations and represent a danger even for skilled workers. The main testing parameters are: the quality of painting or protection of steel-based beams and columns (to avoid corrosion), the quality of part fixers, like fasteners, rivets, screws, etc. and welded joints to avoid collapsing, the clearness of the pipes, surfaces, supporting beams, etc. to avoid pollution etc.

In the last decades, different applications have been envisioned for these robots, mainly in the technical inspection, maintenance and failure, or breakdown, diagnosis in dangerous environments. These tasks are necessary in bridges [3], [4], nuclear power plants [5] or pipelines [6], for scanning the external surfaces of gas or oil tanks [6], [7] and offshore platforms [4], for performing non- destructive tests in industrial structures [8], [9], and also in planes [10], [3], [11] and ships [3], [12].

This is why the development of autonomous non-conventional climbing robot is very important from different points of view such as safety of the infrastructure, safety of the human operators, quality of the inspections and increment of the periodicity of inspection etc. There are two different types of climbing robots: (a) robots that move on at or quasi- at surfaces and (b) robots that change from one plane to another performing 3D motion.

For wall climbing robots, two systems are important namely; Locomotion system (required to move the robot) and Adhesion system (required to adhere the robot on the surface on which it moves.). In the next section both these systems are discussed.

II. TECHNOLOGIES FOR LOCOMOTION

A mobile robot needs locomotion mechanisms that enable the robot moves through environment. Selection of a robot's approach to locomotion mechanisms have been inspired by their biological counterpart.

With respect to the locomotion type, three types are often considered: the crawler, the legged types and the wheeled. Although the crawler type is able to move relatively faster, it is not adequate to be applied in rough environments, being its main disadvantage the difficulty in crossing cracks and obstacles.

A. LEGGED LOCOMOTION

Legged climbing robots, equipped with suction cups, or magnetic devices on the feet, have the advantages of allowing the creation of a strong and stable adhesion force to the surface and easily coping with obstacles or cracks found in the environment where they are moving with the disadvantages of achieving a low speed while requiring a complex control. A representative method for implementing locomotion is the adoption of legs [13]. RAMR 1 is a biped robot with four joints, five links, and a suction adhesion mechanism at the ends of its legs. Structures having from two up to eight legs are usual in these machines. The adoption of a larger number of limbs supplies redundant support and raises the payload capacity and safety. These advantages are achieved at the cost of increased leg coordination complexity, size and weight. Therefore, when size and efficiency are critical, a structure with minimum weight and complexity is more adequate.

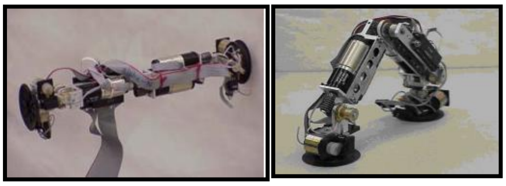

Fig. 2: RAMR 1 Walking On A Surface

B. WHEELED LOCOMOTION

Another possibility of locomotion is to use wheels, being these robots able to achieve high velocities. Wheel-driven climbing robots climb vertical planes and ceilings by combining wheels for translation and rotation and vacuum pumps or magnets for surface attachment. The main drawback of some wheeled robots using the suction force for adhesion to the surface is that they need to maintain an air gap between the surface where they are moving and the robot base. This creates problems with the loss of pressure, or problems with the friction with the surface (if the air gap is too small, or if some material is used to prevent the air leak).

C. TRACKED LOCOMOTION

Tracked climbing robots have a similarity to wheel-driven climbing robots in that both move with a rotational mechanism. However, using a chain-track as the locomotive mechanism, tracked climbing robots are better able to avoid obstacles and adhere to the surface. Cleanbot II [14], which employs a chain track on which *52* suction cups are installed, can virtually achieve continuous movement (Fig. *3*). The vacuum suction cups are controlled by solenoid valves and supply adhesive force to make the robot stick to the glass surface. The robot can turn in a limited range by twisting the flexible chains and climb over an obstacle that is less than 6mm high.

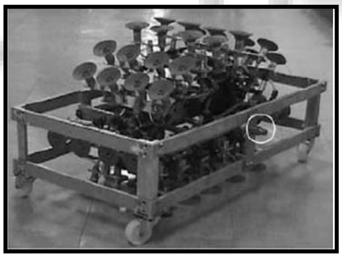

Fig. 3: the main structure of Cleanbot II

III. TECHNOLOGIES FOR ADHESION TO SURFACES

A. MAGNETIC ADHESION

Magnetic attachment can be highly desirable due to its inherent reliability. Despite that, magnetic attachment is useful only in specific environments where the surface is ferromagnetic and, therefore, for most applications it is an unsuitable choice. The most frequent solution is the use of electromagnets [15].

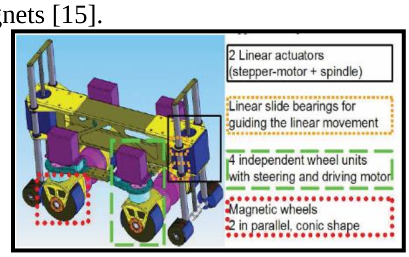

Fig. 4: Conceptual model of robot with magnetic adhesion

B. SUCTION ADHESION

The most frequent approach to guarantee the robot adhesion to a surface is to use the suction force. The vacuum type principle is light and easy to control, allowing climbing over arbitrarily surfaces, made of distinct types of materials, and can be implemented by using different strategies. Usually, more than one vacuum cup is used in each foot in order to prevent loss of pressure (and adhesion force) due to surface irregularities. ROMA II is designed to inspect 3D complex environments with 4-DOF kinematics an example of a biped climbing robot, adopting suctions cups [13]. ROMA II has two legs and a pneumatically driven grasping mechanism. The vacuum system that is adopted for this robot is able to produce a grasping force of 100kg that supports an overall weight of 20kg.

Fig. 5 (a) ROMA II (b) Vacuum cups fo OMA II

IV. NEW ADHESION PRINCIPLES

In spite of all the developments made up to this point, the technologies presented are still being improved and no definite and stable solution has yet been found. Therefore, developments continue in this research area. In the last years much inspiration has been gathered from climbing animals [16]. Insects, beetles, skinks, anoles, frogs and geckos have been studied for their sticking abilities. Beetles and Tokay geckos adhere to surfaces using patches of microscopic hairs that provide a mechanism for dry adhesion by Van der Waals forces. Cockroaches climb a wide variety of substrates using their active claws, passive spines, and smooth adhesive pads. Inspired by these animals mechanisms, new methods for assuring the adhesion, based in biological findings, have recently been proposed.

The first of these machines was latter improved by Murphy [17], giving rise to a small-scale agile wall climbing robot, named Waalbot, able to navigate on smooth surfaces of any orientation, including vertical and inverted surfaces, and using adhesive elastomer materials for attachment Latter, Unver [18] develop another climbing robot, based on these ones, with an weight of 100 grams (including the electronics) and featuring a peeling mechanism for the robot feet, since this aspect is crucial for climbing robots power-efficient detachment (as seen in geckos). This robot is named as Geckobot (Figure 8, right).

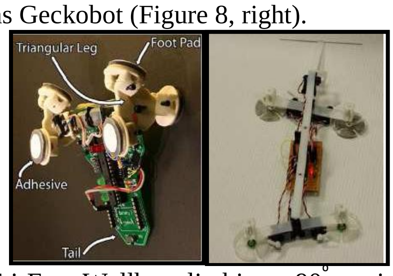

Fig. 6 Tri-Foot Wallbot climbing a 90° vertical surface (left) Geckoboat (right)

V. CONCLUDING REMARKS

In this paper, a survey of climbing robots has been presented. Climbing robots have high potential that have been applied in various industrial fields and investigated for scholastic purposes. With respect to the locomotive and adhesion mechanisms, which are necessary requirements for climbing, climbing robots are classified into different groups. Along with a brief outline of each group, a few representative examples that describe the unique characteristics have been introduced. Many light-weight climbing robots have less payloads causing low applicability to practical tasks that involve carrying various equipment. Otherwise, they are heavy of weight and slow owing to the increase in their size for employing rigid and complex mechanisms for large payloads and high mobility, which leads to low operational efficiency. In terms of further research in the future, it is important to develop climbing robots with such abilities as an appropriate payload, high speed of operation, and high energy efficiency.

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