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Design and Implementation of Climbing Service and Maintenance Robot along Tubular Structures

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Abstract
Climbing robot serves many critical applications for large and high-rise structures, including safe-maintenance, inspection and cleaning. It becomes unsafe for human operator to perform such operation, which could result in catastrophic damage to the property and/or it could harm human lives. Climbing robots can also be used for reaching dangerous places with limited possible access, such as mines, wells and nuclear reactor. This paper proposes a new design for climbing robot with adjustable maintenance-arm mechanism connected to it. The robot is able to climb tubular structures, which can be part of high-rise buildings to perform service and/or maintenance operations. The robot integrates sensors that can detect obstacles. Moreover, the article describes and shows photographs of a prototype built and tested as verification for the proposed approach.

Keywords: Climbing Robot; adjustable arm; tubular structure; Survace; Maintenance;.

1. INTRODUCTION

Climbing robot gained interest and become a major challenge for researchers nowadays. In the literature, one can find several examples for different designs of climbing robots. These existing climbing robots serve many applications. For example Wang and Shao, 1999 presented a climbing robot that can be used for painting large buildings. Many other researchers presented climbing robots that can perform wall and glass cleaning (Qian et al., 2006, Sun et al., 2004). In Qian et al., 2006 the authors presented a robot that can move on smooth glass surface depending on its own gravity and the lifting force of the trolley crane on the roof while adhering to the surface using dual vacuum suction cups. Sun et al., 2004 presented a climbing robot system with several suction cups for adhering to the glass and a transitional mechanism for moving. In Kim et al., 2008 the authors presented a climbing robot with a continuous locomotive motion by adopting a series chain on two tracked wheels on which 24 suction pads are installed. While each tracked wheel rotates, the suction pads which attach to the vertical plane are activated in sequence by specially designed mechanical valves. Loc et al., 2010 presented a study that aims to improve adaptability of quadruped walking and climbing robot in complex environment. They developed a sensing system composed of range and gyroscope sensors to perceive the surface of the environment in real time. In Luk et al., 2005 the authors studied Robug IIs system which is a legged climbing robot. They developed a set of reflexive rules for the robot to react to the uncertainty of the working environment. Some other applications of climbing robots include performing maintenance and inspection that required attaching some equipment to the robot in order to perform the required application. Rosa et al., 2002 presented a climbing robot that is capable to climb up vertical, cylindrical painted iron surfaces by means of eight suction cups, to change its climbing direction, and using the appropriate system to curry an ultrasonic probe or other equipment to evaluate the thickness and integrity of the metal in the inspection of storage tanks.

From the literature, one can find that most of the climbing robot designs have made used of either vacuum suckers or magnets in order to adhere to the surfaces, which might be useful only for smooth or magnet surfaces (Sameoto et al., 2008). This problem was addresses by Sameoto et al., 2008. The authors presented different designs of feet to be used with a spider-inspired hexapod climbing robot and examine their fabrication method and best mode of attaching and adhering to surfaces. Little existing work that can be found in the literature addresses the design of climbing robots along tubular structures. Such designs have many advantages, in contrast with other types of climbing robots with legs (Aracil et al., 2003) due to the fact that it reduces the great numbers of redundant degrees of freedom of climbing robots with legs. In the other hand, such a robot is not flexible to move freely in any direction. It only can move along a tubular structure, which is suitable for performing service and maintenance operation along the tubular structure. Aracil et al., 2003 presented three types of parallel robots capable to climb through the inside and outside of tubular structures. In addition they developed a prototype of parallel robot to climb palm trunks.

The paper proposes a design of climbing robot capable to climb along tubular structure as a part of high-rise building and perform maintenance and/or inspection functions. The robot capable of detecting obstacles, perform curved movements, it also can perform the required operation, using the flexible arm attached to the robot.

The rest of the paper is organized as follows. Section 2 describes procedures adapted for designing the proposed climbing robot. Section 3 describes the controller and the sensors installed. In section 4, we test the proposed model using the Solidworks software package and we build a prototype to perform an experimental validation. Section 5 summarizes the work and offers concluding remarks.