A Cartesian Cable-Based Robot for Large Storage Structures

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***Abstract*—This paper presents the design of a storage robotic system based on a Cartesian cable driven architecture. The proposed mechatronic system can reach large controllable workspaces keeping its suspended mobile platform parallel to the ground. Compared to traditional robotic systems with rigid links, the proposed design uses eight flexible links which are collected and released by pools which are activated by two servomotors, allowing an easy adaptation to extensive storage structures. The cables arrangement; that is, the connection points between the mobile and the surrounding static platforms, permits the mobile platform to move heavy loads on a vertical plane without interferences among cables. The robot workspace is analyzed by simulation in order to validate the feasibility of the optimal configuration.**

***Index Terms*—Cable-based robots, cable driven robots, robot design, storage automation, workspace analysis.**

I. Introduction

THE basic storage industrial systems include the following tasks: moving towards an object, grasping it, moving to a specific location, and releasing the object. Automatization of these operations has resulted in the development of robotic systems working in large-scale storage facilities. Compared to manual operations, the benefits of such systems are several: optimization of the facility workspace, improvement of material flow, and a substantial reduction of misplacement errors. Despite this development, increasing industrial requirements due to global economy changes has motivated the continuing quest for more effective storing systems.

An effective storage system depends on smooth, fast and precise transportation of items along large distances with the minimum energy consumption. Smooth movements reduce unwanted vibrations, actuators damage, and avoid the object escapes from the gripper mechanism. High speed motions during the transportation minimize the traveling time, reducing operational costs. A precise positioning of the moving object at a predefined fixed location results in quick and secure grasping or releasing operations.

Traditional robotic systems used in these processes consist of heavy rigid links that are used to guide and support a mobile platform in which materials are transported. These systems, commonly called Cartesian or Gantry robots, are used in the Lego brick storage structure with 65.6-foot high buildings [1]. Gantry robots are still attractive in many industrial applications for their versatility and easy mechanical analysis and control design. However, their cantilever configuration and high inertia might result in the acquisition of expensive actuators and high power supply systems.

Unlike traditional robots, cable-based robots use flexible links in order to connect a suspended mobile platform to a surrounding static platform. Using cables instead of rigid links brings in principle several advantages: low inertia, fast motions and large range of positioning. The following cable-based robots are representative of those used for commercial and industrial applications: The Skycam [2], a suspended camera, the NIST Robot Crane [3], a crane-type robot, the Deltabot [4], a hybrid robot which introduces a rigid link as spinal, and IPANEMA [5], a spatial robot with eight actuated cables to completely constrain its mobile platform.

A common classification for these robots is based on how cables are used to constrain its mobile platform [6]. Thus, crane-type cable-based robots are classified as incompletely restrained robots because they depend on gravity force to ensure tension in cables. On the other hand, fully constrained robots replaced the gravitational force by active antagonistic cables. Both types of robots face the same limitation: cables only work if tensile forces are applied on them. This cable property results in a physical constraint which requires all cables are working in opposed directions, increasing the number of cables used in the robotic system compared to the rigid ones. Thus, the performance measurement of cable-based robots must include a comprehensive study on cable tension variations along all reachable positions preventing loss of control of the mobile platform.

Different design approaches have been proposed to find realistic solutions to the problem of reaching long distances while cables are stretched. These solutions are based on selecting the optimal anchor points located in both the mobile and the static platforms. Some authors [7], [8] are focused on obtaining a maximum number of degrees of freedom, allowing more diverse poses of the mobile platform, while others [9-12] are focused on develop robots with the sufficient degrees of freedom to accomplish the desired task.

In this paper, a novel robot design is developed to cover the maximum rectangular area with low force actuation. The final robot configuration was based on the optimal arrangement of

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