Constrained Control Scheme for the Manipulation of Heavy Pre-fabricated Elements with Lightweight Robotic Arm

M. Ambrosino[1], F. Boucher [2], P. Mengeot [2], and E. Garone[1]

[1]Service d'Automatique et d'Analyse des Systèmes, Université Libre de Bruxelles, Brussels, Belgium.
[2] NV BESIX SA, Brussels, Belgium.

Michele.Ambrosino@ulb.ac.be, fabian.boucher@besix.com, pierre.mengeot@besix.com, egarone@ulb.ac.be

Abstract -

Building activities involving heavy suspended elements are one of the construction activities with the highest level of danger. Typically, during these activities, one or two masons work in conjunction with a machine such as a crane or a lifting machine. Several robotics solutions have been proposed to replace the masons during these hazard operations. In this work, we propose to use a lightweight robotic arm to handle and place a heavy suspended object ensuring a high level of precision during the planned operations. To control the resulting robotic system, we propose a constrained control scheme based on Explicit Reference Governor (ERG) theory, an add-on unit that modifies the applied reference in such a way that the trajectory of the system always fulfills the constraints of the system. The simulation results show the efficiency of our approach by testing it against other solutions proposed so far.

Keywords -

Robotics; Cooperative Robotic Systems; Building Activity; Robots for Construction; Constrained Control Scheme.

1 Introduction

Various construction activities are based on the handling and positioning of placement of prefabricated heavy elements, such as renovation of facades [1], or construction of walls [2]. These types of activities are carried out through the use of machines, such as cranes or lifting mechanisms, in which the object to be positioned is suspended through a cable. Then, the machine moves the object near its final position and a human being (e.g. a bricklayer), manually finishes the operation by guiding the suspended object for the last few centimeters. The presence of the bricklayer is necessary to ensure a high level of precision in the operations. However, these operations involve heavy suspended objects, which represent possible causes of accidents for the bricklayer (sometimes fatal) [3].

Several approaches have been proposed so far in the literature with the aim of using a robotic solution for this type of construction activity [4, 5]. For a complete overview of the drawbacks and the benefits of the proposed robotic solutions, please refer to [6].

Among the various solutions proposed so far, in this work we focus on the one discussed in [6, 7] in order to improve the preliminary proposed control strategies. The authors show how the cooperation between a crane and a industrial robotic arm is able to perform the positioning of heavy blocks in order to guarantee a high level of precision during masonry activities. The control laws proposed in these two researches are based on an *'ad-hoc'* trajectory for the positioning operations, and as highlighted by the authors themselves these control schemes should be reinforced with a governing unit that is capable of managing the constraints that are present in this type of operations. In particular, the main constraints that must to be considered concern the torque required to the actuators of the robotic arm used during operations. In fact, the robot having to handle a payload much heavier than the maximum permissible payload could find itself in an overload situation which would affect the robot itself.

In this paper we propose the design of a lightweight constrained control scheme for a robotic arm that unlike those proposed so far in the literature: *i*) it does not require any offline pre-evaluation of a feasible trajectory; *ii*) it does not solve any online optimization problems. Moreover, the proposed control scheme always fulfills the constraints of the system.

A general purpose control solution that is able to handle constraints in real-time is Model Predictive Control (MPC) [8]. MPC provides an optimal control strategy through the solution of an optimization problem at each sampling time. However, this kind of control schemes have a high computational cost with respect to simpler control schemes, especially when applied to nonlinear systems, therefore, in practice, its application is still limited [9]. A promising alternative to MPC is to consider a first inner controller to stabilize the system, and then, 'augment' the system with constraint-handling capabilities. This idea is the core of the Reference Governor (RG) schemes [10]. The RG is an add-on unit that filters the desired reference in such a way that the trajectory of the system always fulfills the

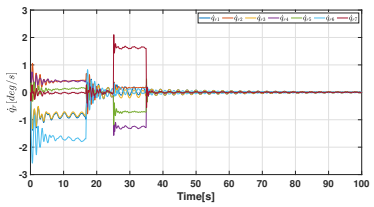

Figure 10. Time evolution of joint robot speed.

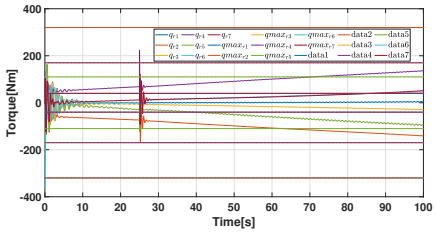

Figure 11. Time evolution of joint robot torques for the control scheme [7].

Robotic Bricklayer: a multi-robot system for sand-lime blocks masonry (réf : 19-PHD-12).

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