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Robust control under uncertainty for seaport handling equipments

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Abstract

Uncertainty in transport includes mainly unavailability of transportation resource, durations of maintenance activities and the infrastructure constraints. The uncertainty influences the transportation resource availability, and consequently the planned transport schedule. Developments presented in this paper are devoted to the robustness control of transportation system. A robust control strategy towards uncertainty is presented. The presented control strategy tries to reduce unavailability of machines in transportation system and to minimize the total transfer time. To illustrate the effectiveness and accuracy of proposed robustness approach, an application to a seaport handling equipments is outlined.

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1. Introduction

In transportation systems operations times are not precisely given, but are included between a minimum and a maximum value. However, some operations have many uncertainties. For example, the time associated to transit

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operations in seaport terminal is uncertain due to various factors and disturbances such as climate, teams' skill and maintenance activities.

The robustness of a system can be defined as its ability to preserve the specifications facing some expected or unexpected disturbances (variations). The robustness is interpreted into different specializations. The passive robustness is based upon variations included in validity time intervals. There is no control loop modification to preserve the required specifications. On the other hand, active robustness uses observed time disturbances to modify the control loop in order to satisfy these specifications.

This paper deals with robust control facing disturbances in transportation systems. The system that motivated this study is typically a real seaport terminal. In the system under consideration, the processing time, that is the times required to perform the operations, are interval-valued. Otherwise, a processing time is selected between two bounds which depend on the operation to be performed. So, any deviations from the allowed lower and upper bounds will lead to a low service quality. Thus, the study of robustness of these systems is needed to be carried out.

The reminder of this paper is organized as follows:

The first section begins by a functional description of the container terminal. The second section uses controlled P-time Petri nets in order to specify the legal behavior. This control oriented tool is applied to model seaport container terminal. The functioning mode under consideration is supposed to be repetitive; therefore a functional decomposition of the Petri net model is proposed. The third section begins by giving some basic definitions concerning robustness of Discrete Event Systems (DES) with time constraints. Afterward, the control problem in transportation systems is tackled. An original approach for the robust control will be presented. The robust strategy tries to reject the disturbance since it is observed using the control. Finally, an application of the control strategy to seaport terminal will be presented.

2. Relevant literature

There has been much research considering the robustness of transportation systems in order to save time and to ameliorate service quality.

Zhang et al. (2014) presented a stochastic robustness analysis and synthesis procedure for the verification and clearance of flight control laws applied to major transport aircraft flight missions. Monte Carlo simulation was utilized to analysis the robustness of the flight control system in the heavy cargo airdrop operation and an optimization algorithm was adopted to search for a stochastic robust controller.

Cats and Jenelius (2015), propose a methodology for evaluating the effectiveness of a strategic increase in capacity on alternative Public Transport Networks (PTN) links to mitigate the impact of unexpected network disruptions. The robustness approach consists of two stages: identifying a set of important links and then for each identified important link, a set of capacity enhancement schemas is evaluated.

Yang et al. (2015) are interested to the problem of the safety management of rail transit. Taking as example the Beijing Subway system (BSS), a complex network theory was proposed to assess the robustness of a subway network in face of random failures (RFs) as well as malicious attacks (MAs). The simulation analysis consists to examine the variations in the network performance as well as the dynamic characteristics of system response in face of different disruptions.

Other control approaches and applications can be found in Mhalla et al. (2013), Dong et al. (2013), Kim et al. (2014), Lee et al. (2015) and Huang et al. (2015).

3. Topology of container terminal

It is admitted that the container terminal is a complex system including the berthing of the vessel, the stevedoring (unloading or uploading) of containers, the transit and the stacking of containers (Roh et al., 2007). Any factor can influence the stay time of ships in port. In this paper, we focus on three important factors: stevedoring of containers, transit, and container stacking. Generally, these tasks are performed by some specific handling equipment. We assume that three types of equipment are used for import or export container as shown in Fig. 1, such as Quay Cranes (QCs), Automated Intelligent Vehicles (AIVs), and Automated Yard Cranes (AYCs).