Designing Traffic-Sensitive Controllers for Multi-Car Elevators Through Evolutionary Multi-objective Optimization

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Abstract. Multi-Car Elevator (MCE) that has several elevator cars in a single shaft attracts attention for improvement of transportation in high-rise buildings. However, because of lack of experience of such novel systems, design of controller for MCE is very difficult engineering problem. One of the promising approaches is application of evolutionary optimization to from-scratch optimization of the controller through discrete event simulation of the MCE system. In the present paper, the authors propose application of evolutionary multi-objective optimization to design of traffic-sensitive MCE controller. The controller for MCE is optimized for different traffic conditions in multi-objective way. By combining the multi-objective optimization with the exemplar-based policy (EBP) representation that has adequate flexibility and generalization ability as a controller, we can successfully design a controller that performs well both in the different traffic conditions and works adequately by generalization in the conditions not used in the optimization process.

1 Introduction

The elevator system is a critical component of high-rise buildings, and its design and control have been studied for many years. The control of cooperating elevator cars for efficient service of passengers is known as "the elevator group control problem". This problem is recognized as a difficult control task, involving stochastic, online scheduling with high combinatorial complexity and real-time response requirements. Since no effective analytical solution has been found to date, current commercial systems are controlled by using a combination of heuristic and artificial intelligence methods [Kim et al., 1998][Beielstein et al., 2003] [Zhou et al., 2005].

Recently, with increasing building heights and more complex usage patterns, multi-car elevators (MCEs) consisting of several cars in a single elevator shaft, usually driven by linear motors, are receiving increasing interest as high-performance transportation systems [Kita et al., 2002] [Sudo et al., 2002]. However, the accumulated knowledge for conventional elevators is not readily applicable to MCEs, which exhibit distinctly different behavior.

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The most promising approach for MCE control appears to be simulation-based optimization, in which the policy of controller is represented by a function model and the parameters are optimized through a simulation. Sudo et al. have shown that the approach with genetic algorithms (GAs) is hopeful [Sudo et al., 2002] [Takahashi et al., 2003]. In those researches, MCE control is performed by assigning a hall-call to a certain car, with using the linear-sum weights $[\alpha_i]$. When a new call occurs, for all available cars, several feature values $[w_i^k]$ expressing the state of the car k are calculated. Then the car with the minimum linear-weighted sum $\sum \alpha_i w_i^k$ is assigned.

In [Ikeda et al., 2006], an exemplar-based policy representation (EBP) [Ikeda, 2005] is employed as a non-linear controller for MCE systems. An advantage of EBP to the controller of linear-sum type is the ability to control flexibly according to the current situation, and the result of numerical experiments has shown its superiority in MCE control.

In those simulation-based researches, the policy of control with adjustable parameters has been evaluated and optimized in a single traffic situation. So, there is no guarantee that the optimized policy works adequately in the other situations, such as in the other building or in the other traffic condition which changes largely depending on such as time-of-day. For practical use, considering the cost and difficulty of detecting and switching the policy depending on the situations, it is preferable that one policy works adequately in various situations as much as possible. In large part of conventional control methods, the current situation is detected by the set of rules such as fuzzy rules, and the corresponding control policy tuned separately is performed. Normally the rules are written out by experts and so very expensive.

In this paper, we employ the multi-objective optimization approach [Deb et al., 2000] [Obayashi and Sasaki 2004] in order to obtain the traffic-sensitive controller for MCE. In this approach, the policy with parameters is evaluated in multiple situations, the objective functions are defined respectively, and multi-objective optimization method is applied. The advantages of EBP for this approach are the ability to control flexibly according to the situation and the ability to generalize it.

This paper is organized as follows. In Section 2, a brief overview of the MCE system and its controller are shown. In Section 3, the simulation-based policy optimization of MCE controller, single-objective and multi-objective, are explained. In Section 4, experiments are done and the result is analyzed, and in Section 5, the paper is concluded.

2 MCE System and Controllers

2.1 Multi-Car Elevator Systems

The almost same MCE system described in [Takahashi et al., 2003] is considered in this study. The elements comprising the system are as follows (see Fig. 1).