Fault-Tolerant Industrial Automation as a Cloud Service

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1 Introduction

Cloud computing requires further research and development to accommodate more application areas [5]. We introduce a new application area: industrial automation. A current industrial automation (IA) system is a multi-tiered architecture entailing different layers from feedback control to enterprise management. If adopted in large-scale IA systems, cloud computing can offer over 40% cost saving and 25-85% time saving [4, 1]. However, IA requires tighter timeliness, reliability, and security than most other cloud applications. We propose a cloud-based IA architecture and focus on the timeliness and reliability requirements. Addressing such requirements for the lowest layer (feedback control) is the most challenging. We addressed the timeliness problem in [2]. To address reliability and further address timeliness, we propose a distributed fault tolerance algorithm for cloud-based controllers. We theoretically and practically prove that the proposed fault-tolerant, cloud-based controllers offer the same performance of the local ones.

2 Fault Tolerance

Our distributed fault tolerance algorithm is run *asynchronously* by all redundant controllers. We call this algorithm *Reliable Cloud Control* (RCC). RCC supports double or higher redundancy and guarantees prioritized engagement and smooth handover of redundant controllers. We prove that the performance of the cloud-based controllers under RCC maintains zero steady-state error and zero maximum overshoot, and we show that the handover effect on settling time is negligible [3].

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3 Evaluation

We performed experiments on both a physical model and an industry-standard emulation of a solar power plant. First, to study the effect of different disturbance models, we performed a series of experiments where cloud-based controllers were deployed on a distant Amazon cloud (in Singapore) to control an industry-standard emulation of the solar power plant hosted on a local machine (in British Columbia, Canada). Through emulation, we inject both deterministic and random disturbance. Experimental results show that the cloud-based controllers perform indistinguishably from their local counterparts under disturbance [3]. Second, to evaluate RCC, we introduced failures in redundant controllers deployed on Amazon clouds that are thousands of miles away form each other (Singapore and Brazil) and from the plant (British Columbia, Canada). Figure 2 shows the performance of a flow control loop of synthetic oil in the solar power plant (Figure 1) under 2 controller/link failure events. Figure 2(a) shows that RCC eliminated the failure effects, while Figure 2(b) shows the importance of the smooth handover ("S.H.") feature of RCC.

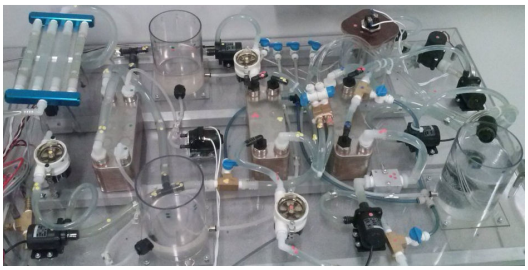

Figure 1: Physical model of the solar power plant testbed.

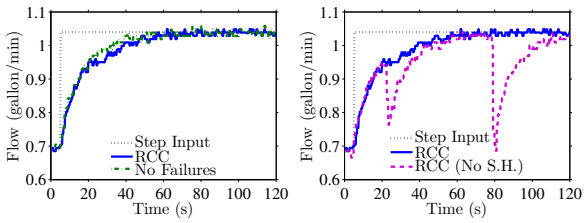

Figure 2: Robustness of cloud controllers under failures.

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