論文の内容の要旨

論文題目: Disposition Strategies and Performance Analysis of Series Configuration Queueing Systems with Blocking Phenomena
(ブロッキング現象を伴うシリーズ構成待ち行列システムの配置戦略と性能評価)

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(本文)

Series configuration queueing systems with blocking phenomena are very common for various applications in real world. For example, assembly line in automobile industry, manufacturing process in semiconductor industry, automated storage system in logistics industry etc. Recently, a popular trend for development of automated systems called “Industry 4.0” and internet of things (IoT) introduce many important concepts that make hardware and instruments connect to each other and collect necessary operational data to analyze(e.g. big data analytics) in order to maximize the efficiency of the whole manufacturing system and reduce unnecessary costs. In the past, we just can obtain the static data and conduct statistical analysis to discover better design methods for these kind of systems. However, with the development of sensor technology, signal transmission system and high performance cloud computing system, the analysis of “dynamic real-time” data become feasible. In the mean time, it is necessary to have related performance information of the system for the engineering designer to make the systems work more efficiently and smartly. Therefore, understanding related performances measures of this kind of queueing system become more important, because we can design algorithms to optimize the efficiency of the system and to monitor possible breakdown phenomena through machine learning techniques based on the information of performance measures corresponding to the processing parameters of each service station.

Queueing theory plays an important role to extract insights from the system consisting of different number of service stations. Series configuration systems generally are composed of several service stations in series. Traditionally, most of researches on the series configuration queueing system and open queueing networks focused on developing algorithms to evaluate steady-state probabilities with equivalent service rate. Other researcher majorly studied the system with blocking phenomena subject to different arrival and service disciplines. In this dissertation, we propose matrix-geometric method to analyze the characteristics of the systems with

infinite waiting space in front of the first service station and there is no buffer between each service station through mean value analysis. The first kind of system is called series configuration systems. Customers should enter each service station from the first station to the terminal station in order to complete the service in the system. The second kind of system is called self-blocking system. Customers can complete the service in one of any service stations in the system. There is no waiting space between each service station for these systems. The blocking phenomena would happen in the case that a customer has completed the service in a station, but another customer still receives service in the next service station. We successfully evaluated steady-state probabilities for the systems with heterogeneous service rates and noticed that different disposition strategies for each service station would cause different performance efficiencies of the system. Furthermore, we investigated that the disposition strategies are different for the system consisting of different service stations. Stability conditions for the system with different number of service stations and restrictions are given. Numerical experiments show the consistent results derived in analytic forms. Exact formulae for some important performance measures can be derived in matrix-form by matrix-geometric method. Important performance measures including mean number in the system, mean number in the queue, mean waiting time in the system, mean waiting time in the queue, blocking probabilities, breakdown probabilities for specific service stations, system reliability probabilities are defined by the evaluated steady-state probabilities. General disposition strategies are proposed for both series configuration systems and self-blocking systems. On the other hand, we also provide transient analysis for the series configuration system. Remarkably, the results of transient analysis show the consistent properties corresponding to steady-state analysis, such as different disposition strategies for each service station cause different performances of the system, the blocking probability of the system with two service stations tend to be 0.33 when the system is in the steady-state. The transient analysis can help us understand more dynamic performance properties of the system.

In this dissertation, we first study steady-state performance analysis of series configuration system consisting of two, three and four service stations with blocking phenomena due to there are no waiting space between each service station. Exact stability conditions for the systems with heterogeneous service rates are derived. General disposition strategies for increasing efficiency of the system are proposed through the results of simulations. In Chapter 3, we investigate transient analysis for the system with two service stations. Important performance measurements are estimated by transient state probabilities. The results of simulations show that the disposition strategies for improving operational efficiency of the system are consistent

in our proposition for the steady-state analysis of the system. In Chapter 4, we consider the system performance subject to breakdowns and repairs. This kind of problems is very important and applicable in real assembly line. Breakdown rate and repair rate of servers are introduced to evaluate related performance measures. Stability conditions are consistent with numerical results. Disposition strategies for increasing operational efficiency of the system are suggested. In Chapter 5, general disposition strategy of self-blocking queueing system is studied. Exact stability conditions of this kind of system with three service stations are derived. We expect that the suggested disposition strategy can be applied in taxi cabs with large capacity of queue in the system. Chapter 6 presents experimental results for the series configuration system with two service stations. We calculate mean waiting time in the queue through real data collected from the experiments in order to validate the concepts that different disposition strategies will cause different operational efficiency for the series configuration system. The statistical analysis of the experimental data certainly confirm that it is better to set higher service rate for the first service station to make the system with two servers work in a efficient way. The results are consistent with our theoretical simulations illustrated in Chapter 2.