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Modeling, Simulation and Optimization for the Medical Treatment Service System based on Discrete Event System Theory

—taking the orthopedic clinic service of the first affiliated hospital of University of South China as example

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Abstract. The phenomenon of hospital queuing and crowding is particularly serious in provincial and municipal third grade hospitals, which greatly restricts the quality and efficiency of medical system service. Therefore, based on DES simulation modeling theory, a simulation optimization method of medical service system is proposed. This project takes the orthopedic clinic service of the first affiliated hospital of University of South China in Hengyang (provincial third grade hospital) as the research object. Observation and investigation is performed on its random characteristics. It uses the FLEXSIM software to establish the simulation model of the medical DES, performs the simulation process with actual data, and carries out the continuous dynamic analysis and optimization according to the simulation system obtained from the quantitative data, so as to improve the performance of the system.

Keywords: Discrete Event System; orthopedic service system; optimizing; simulating.

1 Introduction

1.1 Current Situation

At present, due to the scarcity of resources, the service provided by China's medical system is still difficult to meet the growing demand. The phenomenon of hospital queuing and crowding is particularly serious in third grade hospitals in large cities, which greatly limits the quality and efficiency of medical system services. Moreover, it is likely to cause doctor-patient conflicts and generate knock-on effect. How to effectively describe the distribution and operation characteristics of medical system service resources, quickly perceive, analyze and find the bottleneck that limits the service efficiency of the system, and propose the optimization and improvement strategy, is an urgent problem to be solved.

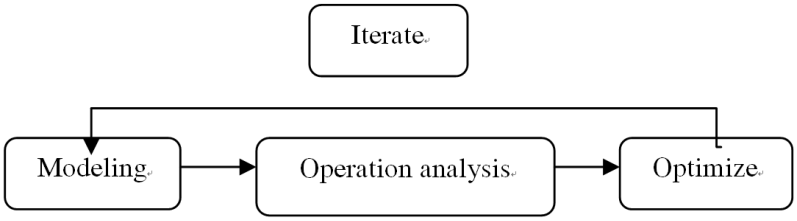
1.2 Related Works

With the advent of cloud computing, Internet and big data era, information perception, computing, storage, transmission and analysis capabilities have been greatly improved. Qu T, Thürer M, Wang J——Motivated by the wide application of industrial Internet-of-Things (IoT) systems, their paper investigates the typical production logistic execution processes and adopts system dynamics to design cost-effective IoT solutions.[11] Xie, T., Li, C.D., Wei, Y.Y., Jiang, J.J. and Xie, R.——To solve the problems of heterogeneity and disorder in the cross-domain integration processes for offsite nuclear emergency response, the integrated decision-making framework of the CDIRS spaces based on Space Mapping and Semantic Web is proposed. With the CDIRS method proposed in their paper, the heterogeneity and disorder can be avoided, and the targets and constraints of the offsite nuclear emergency response problems in the original space can be transformed into the target space, and made unified by formal modeling and ordered reasoning.[12] Ji Fang, Ting Qu, ZhiLi, GangyanXu, George Q.

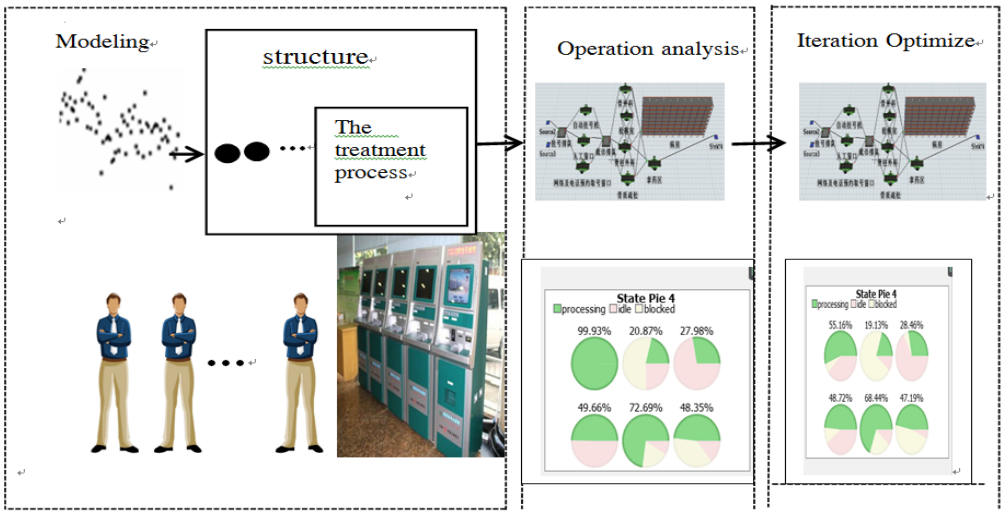
Huang——This paper presents a flexible, modularized and re-configurable framework for the new generation RFID middleware system, named Gateway Operating System (GOS). Based on XML, an easy-to-deploy and simple-to-use application manager is built to manage, configure and use the connected devices as well as deployed applications.[13] Congdong Li, Tian Xie, Yongli Tang——To achieve intelligent integration of the geographically dispersed worldwide manufacturing resource, capacity and service, the intelligent integration framework of Semantic Bill of X (S-BOX) is proposed by combining the technologies of ontology, Semantic Web Rule Language (SWRL) and Bill of X (BOX).[14] Under the new ICT network technology environment, the social system modeling and calculation method based on Discrete Event System simulation provides a more efficient research idea for the optimization of medical service system. Discrete event system is a dynamic system affected by event-driven and leap change of system state. The change in internal state is random, and the same internal state can be changed to a different state. Most social systems can be described by discrete event systems, and the medical service system is no exception as a special social system. So, the doctor or the medical department goes from an idle state to a busy state, or the number of people in a queue is increasing waiting for treatment. Patient arrival and treatment services follow a certain probability distribution, such as thearrival rates (The average number of patients arriving in the queue system per unit of time). The random occurrence of patients and the requirement of orthopedic medical service (patients arrive at the hospital at random to form a crowded queue), the system's medical service ability and the system state affected by the change of demand have strong randomness. At present, DES simulation technique is mainly based on object-oriented visual modeling method, gradually masters the statistical regularity of the change of the system's internal state, quickly turns the real system elements, relationships, layout, operation process, and the uncertain factors into the simulation model, and it provides a strong support for the modeling, analysis and optimization of the orthopedic medical service system.

2 Method

2.1 Principles of Hospital Orthopaedic Outpatient Simulation



2.2 Simulation Optimization based on DES Procedure and Principle of Orthopedics



2.2.1 Model introduction

A patient who reaches the hospital, if has Pre-booked online or by phone, he or she can get the number at the ticket machine. If an appointment has not been made ahead of time, the patient can choose the manual service window or the automatic machine for registration, and after that, he can get into the waiting room and wait in line. The patient went to the department, and the doctor advised him to have a thorough examination or take the medicine. If the patient chooses to have an in-depth examination, the doctor may recommend hospitalization or leave with medication

2.2.2 Modeling

Based on DES theory, Flexsim software was used to model the structure. The hospital orthopedic simulation model is composed of entity and temporary entity flow, which includes equipment (such as automatic registration machine) and temporary entity (such as patient) in the hospital, as well as the relationship between the input, output and influence of entities and temporary entity flow. Through field investigation, data collection, in combination with each department of medical staff configuration and so on, based on south China university first affiliated hospital of medical service system and hospital process, analyzed and summarized the random service rule of All important clinical departments under normal conditions in the end, combined with the feature of the medical service system analysis, through parameter fitting to determine statistical regularity of patients.

2.2.3 Iterating and Optimizing

The simulation results show that the key data of the system model is operated through the simulation model, such as the service efficiency of automatic registration machine and the proportion of queue area. The main bottleneck of outpatient service in orthopaedic hospitals can be obtained by analyzing these data. And can propose the optimized scheme on this foundation.

After the optimization of the original model, new bottlenecks are found, and an optimization method is proposed to analyze the service efficiency and queue area utilization ratio so as to adjust the distribution of the automatic registration machines until a satisfactory solution is obtained.

3 Simulation Results and Discussion

By establishing the simulation model of hospital, the process of patients' visit to the hospital was set up. Taking the orthopedic clinic as an example, the patient's medical procedures include registration, consultation, examination and hospitalization. The patient arrival is a random discrete event. According to the need of orthopedic inspection, CT room, bone density inspection room, X-ray room and nuclear resonant room are set up. According to patients condition the inpatient department is set up. The relevant parameters are set as follows:

Patient arrival rule	class A (entering the hospital hall 1): Exponential Distribution with mean 30 (seconds)
	class B (entering the hospital hall 2): Exponential Distribution with mean 20 (seconds)
	Different types of patients obey Random Discrete Distribution
Automatic registration machine	the average registration time is 25 seconds, the maximum capacity is one
Manually registration window	the average registration time is 35 seconds, the maximum capacity is one person
Queuing machine	the average number timeis 15 seconds, the maximum capacity is one person
Spinal surgery clinic	average treatment time of 30 seconds per person
Bone surgery clinic	the average treatment time is 30 seconds per person
Osteoporosis clinic	average treatment time of 35 seconds per person
Spine surgery clinic	3 persons
Bone surgery room	2 persons
Osteoporosis clinic	2 persons
The examination room	average of 15 seconds per person, the average capacity was 4 people
Spine surgery clinic	average diagnosis time of 60 seconds per person
Bone surgery clinic	the average diagnosis is 55 seconds per person
Osteoporosis clinic	average diagnosis time of 50 seconds per person

Orthopedic inpatient areas	400 persons, on average, 400 seconds per person
The maximum capacity of each queue	200
The total time of the simulation	more than or equal to 400000 seconds

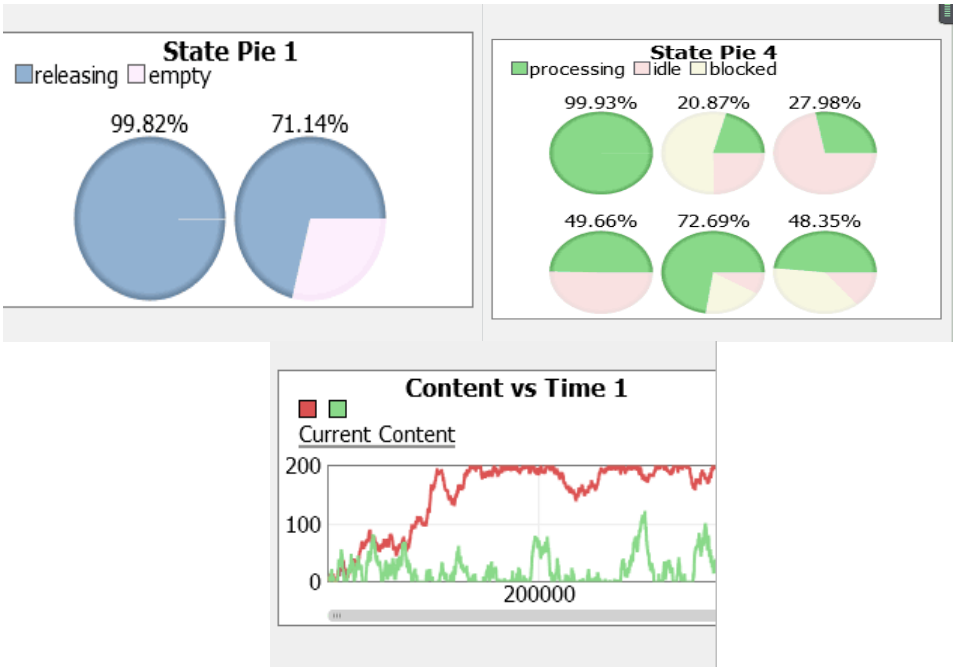


Figure 2. The screenshot of simulation data before optimization

After 400000 seconds of simulation, Automatic Windows and automatic registration machine work time ratio are 27.98%, 99.93%. With the progress of science and technology, more and more people will choose automatic on-site registration, which makes automatic registration machine in full load condition. It is not difficult to find more and more personnel in the queue area, until the maximum capacity is reached. But working hours in queue area is 70%, most patients are stuck in the registration area. Queuing machine working time is 49.66%, having much idle time. Under the premise of registered at the scene, the effective working time ratio of the manual window is only 27.98%. Obviously manual window and Queuing machine are not the cause of blockage, but automatic registration machine cannot meet the requirement of more and more patients. So the process creates a bottleneck that limits the efficiency of the system.

Second, from the charts of each process, we find that the working time ratio of the automatic registration machine has reached 99.93%, indicating running at full capacity. There are still a lot of people queuing, which can be the bottleneck of the system.

After the bottleneck position is determined, we can analyze its reasons. The hospital hall averages 25 seconds to one person. The maximum capacity of the automatic registration machine is 1. The average time required for registration is 25 seconds. Then, why are there so many people in the queue? The reason for the backlog is system randomness. The arrival of the people obeys the exponential distribution, with the mean of 25 seconds. However, a person's arrival in a faster situation often occurs, causing a lot patient overstock in the queue If the automatic registration machine is not changed, the model will continue to queue more people, so on the one hand, the capacity of the queuing area will continue to increase until there is no space left, on the other hand, it will reduce the efficiency of hospital treatment. Therefore, the maximum capacity and registration speed of the automatic registration machine must be improved, and the automatic registration machines will be added to the gap space and beside the ticket outlet, so that three people can operate a machine at the same time. Moreover, the interface of the registration is simplified, the operation is simpler, and the patient's registration speed is improved.

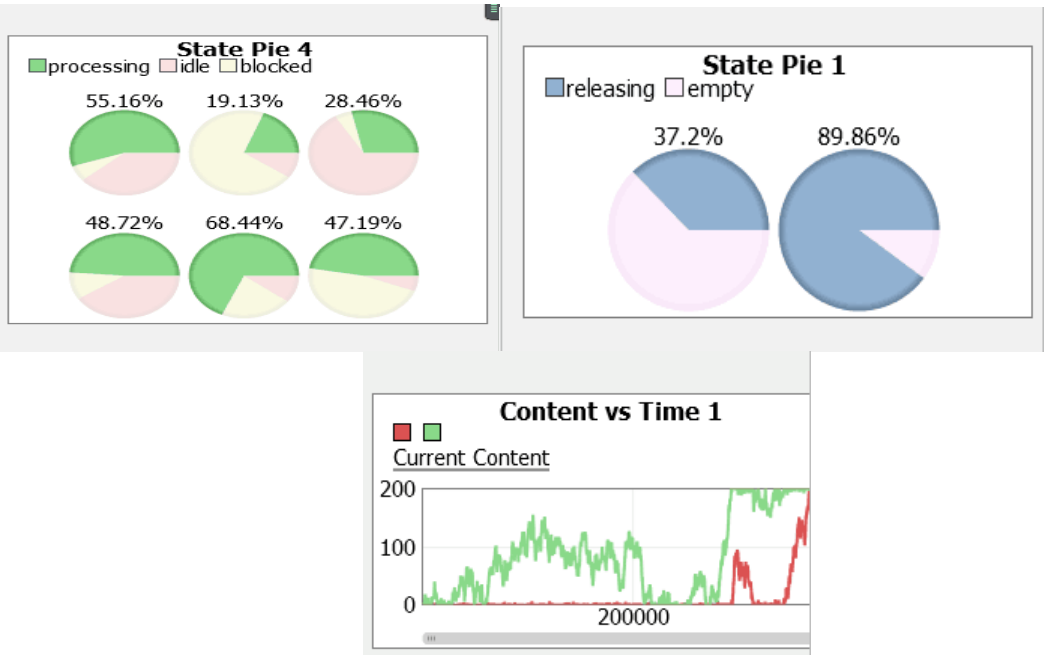


Figure 3. The screenshot of simulation data after optimization

According to the result data, registration queue area personnel are greatly reduced because of the change of capacity and operation speed of the automatic registration machine, so the efficiency of the orthopedic medical service is improved as a whole. Table 1 shows the relevant annotations for the main entity names.

Table1. The relevant annotations of the main entity names

Model entity	System elements	Remark
Person	Patient	Different entity types represent different types of patients, the different types of patients obeys uniform Distribution and different colors represent class A, class B
Processor	Automatic Registration Machine	The processor for registration
	Orthopedic Clinic	The processor for diagnose service
	Examination room (CT, Bone Density, X-ray, Nuclear Magnetic Resonance)	The processor for patients to finish specific inspection
Queue	Queue area (Registration awaiting diagnosis)	Patients waiting in “Queue” for registering or diagnosing
Source	hospital hall	The source from which patients come from
Sink	Hospital export	The sink through which patients leave

Data show that the arrival of the patients is at the same speed as the prerequisite, automatic machine work time ratio is 55.16%, registration queue area utilization ratio is 37.2%. The load of automatic registration machine is reduced, and fewer people are waiting in line, while the effective working time ratio of the queue area has increased to 89.86%, suggesting that automatic registration machine becomes more efficient, and the orthopedic clinic process becomes smoother. The patients’ waiting time gets shorter, the orthopedic service efficiency has been obviously improved. Overall, the service efficiency of the hospital is also improved.

4 Conclusions

The queue congestion in hospital is a common problem, solving the problem of hospital queuing will increase the effective treatment time, enhance the patient's satisfaction, and improve the efficiency of hospital service.

This research adopts the simulation technique and the process optimization provides the reference for hospitals to improve medical services. Compared with traditional optimization methods, such as total quality management and redundant modeling, the simulation technology can respond more accurately to the patient's flow situation, identify the problem of congestion, and predict running state of alternatives plans, thus choosing the optimal scheme and avoiding the subjectivity of artificial selection.

Based on DES systems, we study the modeling, simulation and optimization for the medical service system, and carry out simulation experiment for the patient for orthopedic treatment. It is easy to find that queuing time in the registration area is long, effective clinical time ratio is small. By establishing process model of the orthopedic clinic, and using simulation software with the actual data, the data analysis finds that changing the capacity and operation speed of the automatic registration machine is efficient. After optimization, automatic registration machine work time ratio is decreased, queue number is decreased significantly, which greatly reduces the invalid time, and improves the efficiency of the orthopedic clinic visits, and thus greatly improve the efficiency of hospital medical service.

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