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Research Article

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A System Dynamics Based Simulation Model for Reliability Evaluation of Large Scale Information Systems

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ABSTRACT

The work of reliability evaluation is critical to the availability of the large-scale information systems. The large-scale information system consists of many components. And the reliability depends on the internal structure, parameters and overall functions of the system, which is presented by the work flows of the components. The general approach of system analysis can't cope with the problems of complexity and time-variance of the large-scale information systems. A reliability evaluation model is proposed based on system dynamics, which has advantages in dealing with the problems of complexity and time-variance of systems. By simulating the information flows of billing system of NGBOSS using the approach of system dynamics, the values of reliability are simulated and compared with the actual values, which proves that the proposed model is effective.

Key words: information system; reliability evaluation; system dynamics; information flow; billing system

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INTRODUCTION

Reliability is critical to the availability of the information system. Reliability of information system refers to the ability to complete certain functions under certain conditions and within certain time. From this appoint of view, the reliability consists of three elements: time, conditions and functions. The reliability of information systems involves correctness, maturity and fault tolerance, etc. It takes the frequency of occurred problems into account and involved running experience and the influence of errors directly. The evaluation of reliability refers to performed quantitative measurement to the given property which belongs to the system and can affect the system, including the reliability of hardware and software [1]. Currently, customers are increasingly demanding, the life cycle of products are becoming shorter, greatly increasing the running of information system of uncertainty, diversity and dynamics, presenting the model of complex dynamic behavior, increasing the difficulty of maintaining the information system [2]. For this kind of delaying, uncertain and dynamic problems, the traditional static approaches are very difficult to play a role. System dynamics was started by professor Forrester of MIT in the 1950s, and provides a feasible method to solve the delaying, uncertain and dynamic problems.

System Dynamics integrates Feedback Cybernetics, Information Theory, System Theory, Decision Theory, Computer Simulation and the Experimental Approach to System Analysis [3]. In the method, the viewpoint of system thinking is employed to define the boundary of system organization and transfer process, the Causal Feedback is employed to present the Dynamic Complexity of the system, and establish the quantitative model to simulate behavior patterns of the real system under different strategies, helping researchers to understand the dynamic behaviors of the system [4]. In this research, System Dynamics would be used to evaluate the reliability of large-scale information system.

1. SYSTEM DYNAMICS

This section consists of four aspects of system dynamics: the concept, principles, the causal loop diagram and the stock and flow diagram.

1.1 THE CONCEPT

System dynamics starts from the microstructure inside the system, presents the internal structure, parameters and overall functions, and analyzes the behavior of the system. System dynamics is essentially a group of differential equations of first order with delay. In this method, the stock and flow diagram is used in the process of modeling. In the diagram, all of levels of stock, rate of flow and auxiliary have clear physical meaning. It is a practice oriented modeling method of structural type. Its main characteristic is that it can conveniently deal with the nonlinear and time-varying object, and can be used to conduct long-term, dynamic and aggregate simulation analysis.

1.2 THE PRINCIPLES

System dynamics is essentially a computer model method based on the systematic thinking. Generally speaking, the difference between the systematic thinking and system dynamics method is: the systematic thinking method does not include the simulation process and the method of system dynamics provides the simulation results by modeling and simulating the process of the system. The systematic thinking method is fundamentally different from the traditional form of analysis. In the traditional analysis, the research object is divided into independent parts. In contrast, in the systematic thinking, as a part of the research object, its interaction with the other components of the system is focused on. And the system is defined as a series of elements with interaction behaviors. This means that, different from the analysis approach, in which the system is isolated into smaller parts of the object, in the systematic thinking approach, a growing number of components of the object are connected to conduct the research. This sometimes results in the completely different conclusion with the one from the traditional analysis. This happens especially when the research objects have the characteristics of complexity and time-variance.

In system dynamics, the large-scale system is defined as a nonlinear feedback structure with high order and multi loops. A system consists of the units, activities of units and information. Unit refers to the realistic foundation of system, and the information plays a key role in the system. System units form structure by relying on information. The activities of units are the basis of behaviors and function of systems.

Generalized systems are divided into the open loop systems and the feedback systems. In large scale systems, feedback loops are in the structure of mutual connection and mutual restriction. All of information systems are information feedback systems. In information systems, the feedback loops connect the key variables and other variables. And these variables affect the systems' operation [5].

1.3 THE CAUSAL LOOP DIAGRAM

The causal loop diagram can clearly present the nonlinear connections in systems. In the causality diagram, the feedback loops are its elements. The feedback loop is a closed path of a series of causes and effects. The number of feedback loops is a sign of the complexity of the system. From the perspective of causality, two system variables can be mutual positive, negative, no relationship between or complicated relationship.

1.4 THE STOCK AND FLOW DIAGRAM

The stock and flow diagram consists of three elements: the stock level, the flow rate and information. In system dynamics, the diagram is the basis of modeling using system. In the stock and flow diagram, the stock level is the accumulation of vary with time and is the stock box of material, energy and information.

The stock and flow diagram can used to clearly present the feedback relationship in systems. In the diagram, the relationship between variables is defined by formula or equations. The relation between the stock level and the flow rate is the first order differential equation. In large scale systems, with the increasing of the order, the order and the number of equations will increase. Therefore, compared to the traditional analysis, computer simulation modeling has the advantage of using computer simulation to solve the equations.

2. RELIABILITY EVALUATION OF LARGE-SCALE INFORMATION SYSTEMS

The failure of information systems is divided into hardware failures and software faults in general. The reliability evaluation of information system, therefore, is divided into hardware and software evaluation. There are significant differences between the two evaluation methods as they failed for different reasons. Hardware failure is usually caused by the aging of components, and software failures are often due to design defects or overloading the computational load, etc. Therefore, it is important to make a distinction on the type of faults.

2.1 THE FAULT TYPES

The fault types are caused by hardware failures and software failures.

1) Hardware failure

There are a variety of reasons that produce hardware failure including hardware unstable, aging of components and

harsh environments.

For the information system threatened by hardware failures, the reliability can be evaluated from the relations between the connected hardware. In the general, the hardware structure can be in a hybrid form of series and parallel [6].

Figure 1. The series structure of hardware failures

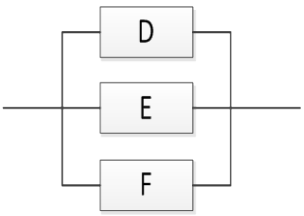

Figure 2. The parallel structure of hardware failures

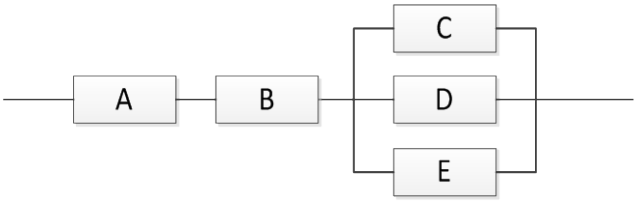

Figure 3. The hybrid structure of hardware failures

In figure 1, the hardware series structure is presented. In the structure, each component's failure can cause the failure of entire structure. The reliability of this structure is the product of the reliability of each component.

$$R = R(A) * R(B) * R(C) \quad (1)$$

In figure 2, the parallel structure of hardware is represented. In the structure, the failure of each component will not cause a system failure, and this structure has the characteristics of disaster tolerance. The reliability of this structure can be represented as the following formula.

$$R = 1-(1-R(D)) * (1-R(E)) * (1-R(F)) \quad (2)$$

Figure 3 is in the form of a hybrid structure, and the reliability of the system described in it can be represented as the following formula.

$$R = R(A) * R(B) * [1-(1-R(C)) * (1-R(D)) * (1-R(E))] \quad (3)$$

2) Software failure

The quality of software is connection with a lot of factors, including the development environment of software system, the complexity of functionality, the level of production management, the quality of the developer and the material of software production (the development time, funding etc.). A narrow understanding of the reliability of software system is that the probability of failure-free operation of software in a specific operating environment and a specific period of time.

2.2 THE RELIABILITY EVALUATION

The reliability evaluation of software can be carried from different perspectives. One is evaluated from the structure of software. And the other one is evaluated through a reliability evaluation model. The determinants of reliability of software is the error of software which is connected with input data, is a function of data and the state of internal program, which can be measured by the probability of fault $\lambda(t)$ (the probability density of failure in the dimension of time), and reliability $R(t)$ (the probability of failure does not occur within the time interval [0, 1]) [7]. Addition to the single process reliability, the more important indicator to calculate the reliability in software is the reliability of the software as a whole, which requires analysis of the structure of the software. It should be treated differently when calculate the reliability between the different information system, since different systems concerns different

focus.

3. THE SYSTEM DYNAMICS BASED RELIABLITY EVALUATION MODEL

The system dynamics model is composed by the causal loop diagram and the stock and flow diagram.

3.1 THE CAUSAL LOOP DIAGRAM OF THE BILLING SYSTEM OF NGBOSS

In the causal loop diagram, there are three loops: the recharging loop, the product using loop, and the unsubscribing loop. In the recharging loop, the balance would increase when the user recharge. In the product using loop, after the user subscribed and used the product, the balance would decrease. In the unsubscribing loop, after the user subscribe product, if the user unsubscribe the product, the balance would increase. The loops are presented in figure 4.

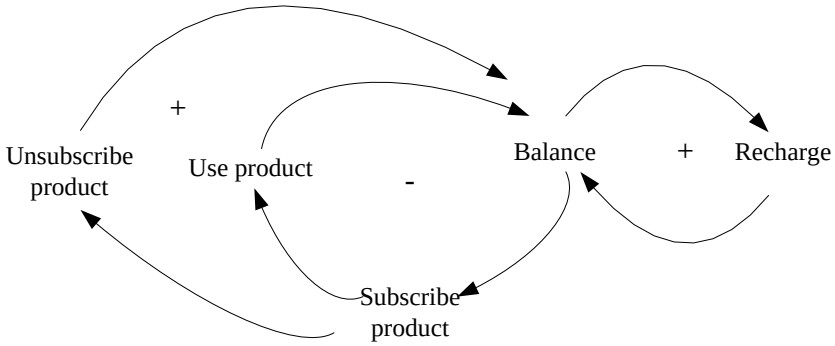

Figure 4. The causal loop diagram of the billing system of NGBOSS

3.2 THE STOCK AND FLOW DIAGRAM OF THE BILLING SYSTEM OF NGBOSS

The stock and flow diagram is given in figure 5.

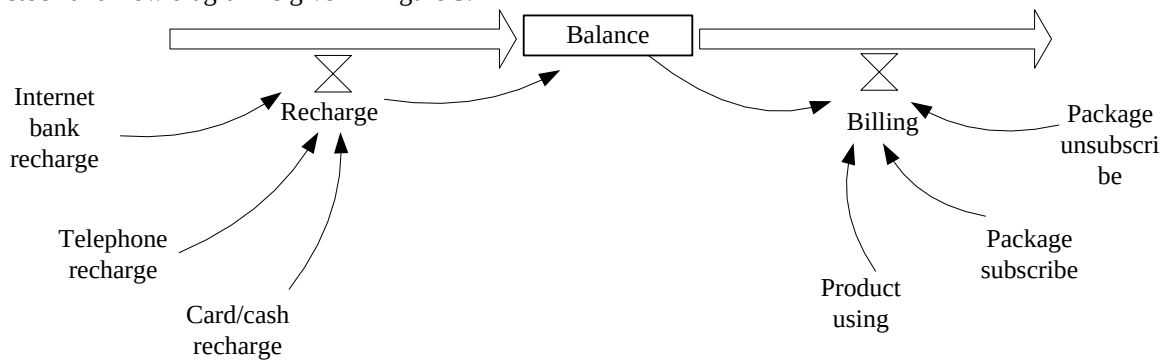

Figure 5. The stock and glow diagram of the billing system of NGBOSS

The balance is affected by the activities of recharging and billing. The user's behavior of recharging would increase the value of his or her balance. The behavior of billing would decrease the value of balance. There are three ways of recharging: Internet bank recharging, telephone recharging and card/cash recharging. And the user's actions of package subscribing, package unsubscribing and product using would take effect on the value of billing.

4. AN APPLICATION OF RELIABILITY EVALUATION TO BILLING SYSTEM OF NGBOSS

The architecture of the billing system of NGBOSS is represented in figure 6.

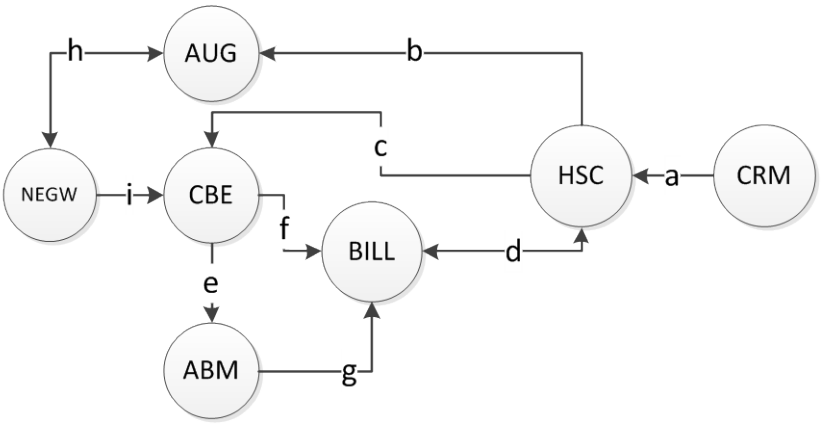

Figure 6. The architecture of the billing system of NGBOSS

In the starting of the process, the billing system of NGBOSS synchronize user's ordering information from CRM to HSC (a database used for store the user's basic information), and AUC (Authorization Center), CBE (Charging and Billing Engine) and BILL (integrated management platform of bill) update their information through refreshing the memory separately from HSC subsequently. Then CBE designated price for the real-time consumer bills of the products authorized by the AUC-p0 from NEGW (Network Element and Gateway), and change the balance in ABM according to the price be designated. Ultimately, BILL will generate consumer records according designated price and movements of balance.

Such a design make a step forward compared to the previous generation billing system of China Mobile Group Guangdong Co., Ltd. The key pointed of reliability in billing system of NGBOSS, from the perspective of security, can be considered as the reliability of synchronization for user's data, since the charging function of NGBOSS is implemented depended completely on the data's synchronization of the databases of the different functional modules, to a system, in particular, which has an amounts of data owned. We, therefore, can evaluate the reliability in the billing system of NGBOSS through evaluate the reliability of information synchronization between the different subsystems.

In actual operation, we take months to be time unit to measure reliability, since the accounts of China Mobile's customer are settled on a monthly basis generally, and get the reliability of sub-process through examine the consistency of user information in different sub-modules per month.

Taking into account that the amount of data in the database is too large to collect and calculate, so we use the sampling method to data acquisition, and according to a fixed product categories, fields and time limits to extract. The simulated model based on system dynamics was implemented on the platform of MATLAB 2011. And the simulated values is given in table 1 for comparing with the actual values of reliability.

Table 1. Comparison between the reliability values of simulated system and the real system for subscribing information

Ordinal	The number of users in April, 2013	Recorded number in CRM	Recorded number in HSC	Recorded number of deviation	Actual reliability	Simulated reliability
1	use product A	32190	32190	0	100%	100%
2	subscribe and use product B	11032	11031	1	99.991%	99.912%
3	subscribe and use product C	1188	1190	2	99.832%	99.823%
4	subscribe and use product D	1113062	1112285	1530	99.863%	99.801%
5	subscribe and use product E	20929	20922	7	99.967%	99.971%

CONCLUSION

Reliability evaluation of information system is a complex problem of systems engineering, and it need us to have a deep understanding of the system structure, to have sufficient understanding of the various process in the system. To cope with the problems of nonlinearity and time-variance of large scale information system in reliability evaluation, a system dynamics based reliability evaluation model was proposed. And the experiment proved that the model is effective.

Acknowledgments

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