Applied Mathematics & Information Sciences
An International Journal

A New Method for Modeling Complex Network Topology of Software Systems

Hailin Li, Jihong Han and Yadi Wang

Zhengzhou Information Science and Technology Institute, Zhengzhou 450004 P. R. China

Received: 12 Jul. 2012, Revised: 10 Nov. 2012, Accepted: 1 Dec. 2012
Published online: 1 May 2013

Abstract: Many large-scale software systems have unprecedented complexity. The basic problem lies in how to construct a complex network topology models that can reflect the complexity of software systems. Based on studying the theory development and application status of complex networks, the complex network topology rules based on component of software system are proposed, the formalized definition of software complex network model is proposed and the application value of software complex network model is prospected. These provide a positive theoretical inspiration and reference value for applying the complex network achievements to the next generation software engineering.

Keywords: Software complex networks, modeling, software complixity, complex network topology.

1 Introduction

With the rapid development of information technology and modernization of industry, software systems and their security have become significant dependence of construction and application of information infrastructure. Because of the large scale and the increasing complexity of software systems, it sets an even higher demand on security and reliability of software systems. Thus, software developers and users pay more attention to performance, security and reliability of software systems, and the assessment of software quality has become more important.

As a new cross branch of learning, network science, which is built on the basis of complex network theory, has achieved more achievements in real complex systems of many different science fields researches. This article makes attempt to apply complex network theory to modeling software system, to study the complex network characteristics of software systems, to propose a novel topology rules and definition for software complex network model, to make valuable exploration by analysing and evaluating of software complex networks.

In accordance with the present condition of complex network theories and complex nature characteristic of software systems, the modeling method of complex network models of software system was studied, the topology structural rules of constructing software complex networks were proposed, and the formal definition of this model was proposed.

2 The theory development and application status of complex networks

The notable landmarks of complex networks. The development of network theory benefited from the development of applied mathematics such as grahp theory and topology[1]. The first appearance of graph theory is in Leonhard Eüler's book in 1736, it originated from the famous seven bridges in Königsberg. Eüler simplified this problem as the first graph theory which was called Eüler Graph by abstract analysis, and he created a new mathematics branch–graph theory. This is an initiative contribution to network science, and Eüler was praised as the father of graph theory[1].

Another milestone-like contribution of network science is the random graph theory which is built by Edös and Rényi in Hungary in the end of 1950s[2]. Edös and Rényi used the relative uncomplicated random graph to represent networks(called ER random graph theory for short), their important finding is that many significant characteristics of ER random graphs are emerged unexpectedly with the growth of network's scale.

* Corresponding author e-mail: lihl_c@yahoo.com.cn

At the end of 20th century, scientists broke through the long-term bound of traditional graph theory, especially random graph theory, and achieved an important breakthrough in complex network researches. The milestone mark was the discovery of small world network[3] and scale free network[4]. The two initiative theoretical achievements, small world effect and scale free property, laid the foundations of complex network theory. Thus, it had been born a cross science named network science[1,5], and marked the research of complex network entering upon a new phase of network science[6,7,8]. It aroused different researchers' high attention to and universal participation in network science, and became one of the most hot sciences all over the world[1].

Application status of complex networks. As a description way of complex systems, network science exploits new fields for other cross sciences such as graph theory, statistic physics and nonlinear theory, and has contributed to revealing the constructions, functions, characters of dynamics and their relations. With studying theories and applications of network science in a deepgoing way, it will reveal the laws and secrets of objective world, and bring benefit to mankind[1].

To describe the properties of complex networks, the scientists have proposed many concepts, characteristic quantities and measurement methods to represent the topology characteristics and dynamics characteristics. The concepts and characteristic quantities of networks include degree centrality, clustering coefficient, betweenness centrality, degree correlations, modularity and so on[1,8-10]

Networks have been the objects of interests for scientists from many different areas such as physics, mathematics, computer science, engineering, social science and biology. Mana real systems are revealed to share network structures, such as computer internet, world wide web, food webs, scientists collaborative networks, power networks, Neural networks.

3 Complexity study of software system

Complexity as an inherence of software systems. Complexity is an inherence of software systems[11]. With softwares being developed in many fields of information systems, the functions and structures of sofeware systems are more and more complex(showed in Fig. 3.1), these raise the difficulty of developing, testing, evaluating and maintaining softwares.

Complex network characteristics of software system. There are different grain-size units for realizing software system, such as functions, classes, interfaces, 1ibraries, compiling units, packages, and so on. And there are many interactive relations in these units.

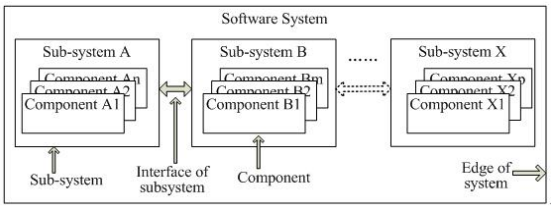

Figure 3.1 Hierarchical structure of software system functions

Network model is a valid model to describe large complex systems, we can view software system as complex networks, set different security functions as vectors, set their relations as edges. Thus, we can understand the formation and evolution of software system though analying the network structure topology and modeling technology.

4 Complex network model of software system

Graph theory is a framework for handling complex network problems, and complex networks can be expressed with graphes in formal[12][13].

Definition 1(Network(Graph)[14]): A network consists of a set of vertices and edges, where an edges connects two vertices. Mathematically, a network is represented by a graph G={V(G),E(G)}, where V(G) is a set of vertices and E(G) is a set of edges in a graph G. If the set of edge E is a set of ordered pairs of vertices, G is directed graph, If the set of edge E is a set of unordered pairsof vertices, G is undirected graph.

The network is a large system consisting of many similar parts that are connected together to allow movement or communication between or along the parts or between the parts and a control centre. These parts are equivalent to vertices, and these connection relations are equivalent to edges. When studying complex network structure, we model complex network of software systems by means of viewing components as vertices, abstracting dependent relations of components as edges, and viewing precedence of executing functional components as direction of edges.

Definition 2(Software Complex Network Model, SSCNM): A Software Complex Network Model(SSCNM) is a binary direction graph GSCNM={C, E}, where C is a set of components realizing security functions and E is a set of dependent relations of components, and the directions directing to the objective components.

The topology rules of modeling software complex networks are critical content of software systems. The topology rules of software complex networks showed as Fig. 4.1, 4.2, 4.3.

Figure 4.1 The topology rule of sequential executive components

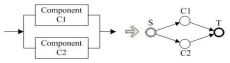

Figure 4.2 The topology rule of parallel executive components

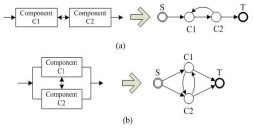

Figure 4.3 The topology rule of complex components existing interactive and hybrid relations

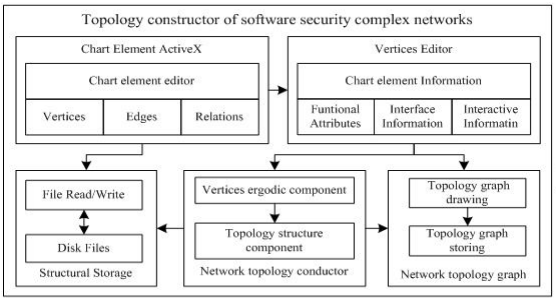

Figure 4.4 The functional composition of topology constructor

With the above rules, the topology constructor of software complex networks was designed. The functions of this topology constructor are showed in Fig. 4.4.

5 Conclusion

The study of complex network in software engineering is few, though study achievements of network are emerging in other fields. The studies of complex network in software engineering show that the large software systems have small world effect and scale-free characteristic[15,16,17], but these are initial results.

Complex network applying to software engineering is beneficial to researchers understanding and optimizing software products. [18]The complex network achievements of software systems will lay the foundations of analysing and optimizing software architectures, measuring and evaluating software quality, and developing the next generation software engineering.

Acknowledgment

We are grateful to the anonymous referee for a careful checking of the details and for helpful comments that improved this paper.

References

[1] Fang Jinqing, Wang Xiaofan, Zheng Zhigang, et al. New interdisciplinary science: network science(I)[J]. Progress in Physics, 2007, **27(3)**: 239-343 (2007).
[2] Erdös P, Rényi A. On the evolution of random graphs. Publ. Math. Inst. Hung. Acad. Sci., 1960, **5**: 17-60. (1960).
[3] Watts D J, Strogatz S H. Collective dynamics of "small-world" networks[J]. Nature, 1998, **393(6684)**: 440-442. (1998).
[4] Barabási A L, Albert R. Emergence of scaling in random networks[J]. Science, 1999, **286(5439)**: 509-512. (1999).
[5] Barabási A L. Linked: The New Science of Networks[M]. Massachusetts: Prerseus Publishing. (2002).
[6] FANG Jin-qing, WANG Xiao-fan, ZHENG Zhi-gang. Several Advances in Theoretical Modeling and Related Application Subjects for Network Science[J].COMPLEX SYSTEMS AND COMPLEXITY SCIENCE. 2008, **5(4)**, pp. 1-20. (2008).
[7] Bianconi G, Barabási A L. Europhys. Lett., 2001, **54**: 436-442 (2001).
[8] WANG Xiao-fan, LI Xiang, CHEN Guan-rong. Complex networks Theory and its Application[M]. Beijing: Tsinghua University Press. (2006).
[9] Fang Jin-qing. Rapidly Developing Study of Complex Networks and Its Challenges[J]. Chinese Journal of Nature. 2005, **27(5)**, pp. 269-273. (2005).
[10] ZHENG Xiao-long, ZENG Da-jun, LI Hui-qian, et al. Analyzing and Modeling Open Source Software as Complex Networks[J]. Complex Systems and Complexity Science. 2007, **4(3)**, pp. 1-9. (2007).
[11] LI Bing, MA Yutao, Liu Jing, et al. Advances in the Studies on Complex Networks of Software Systems[J]. Advances in Mechanics.2008, **38(6)**, pp. 805-814. (2008).
[12] FANG Ai-li, ZHAO Ji-jun. Complex Networks: Structure and Dynamics[J]. Complex Systems and Complexity Science. 2006, **3(3)**, pp. 56-94. (2006).
[13] S. Boccaletti, V. Latora, Y. Moreno, et al. Complex Networks: Structure and Dynamics[J]. Physics Reports, 2006, **424(4,5)**, pp. 175-308. (2006).
[14] Zhenhua WU. Physics of Flow in weighted complex networks[D]. Boston University. Doctor. (2008).
[15] Sole' R V Ferrer R, Montoya J M, Valverde S. Tinkering and emergence in complex networks[J]. Complexity, 2002, **8(1)**: 20-33. (2002).
[16] A Potanin, J Noble, M Frean, Robert Biddle. Scale-free geometry in object-oriented programs[J]. Communications ofthe ACM. 2005, **48(5)**: 99-103. (2005).
[17] Liu Bin, Li Deyi, Li Bing. Mining representative nodes in scale-free networks[J]. Dynamics of Continuous Discrete and impulsive Systems. 2006, **13(3)**: 395-400. (2006).
[18] M. Yu. Rasulova, The Approximative Hamiltonian for Dicke Model Defined in Terms of the One-Zone Potential, Applied Math & Information Sci., Mag. **2**, 173–186, (2008).

Hailin Li is a doctorial student in Zhengzhou Information Science and Technology Institute, China. He obtained his M.A. from Zhengzhou Information Science and Technology Institute in 2006. He has published more than 20 research articles in reputed international journals of software engineering and computer sciences. His research interests are in the areas of information systems and software security.

Jihong Han is a a professor in Zhengzhou Information Science and Technology Institute, China. She obtained her PhD from Zhengzhou Information Science and Technology Institute. She is a supervisor of PhD candidates. She has been an invited speaker of number of conferences and has published more than 60 research articles in reputed international journals of software engineering and computer sciences.

Yadi Wang is a professor in Zhengzhou Information Science and Technology Institute, China. He is a supervisor of PhD candidates.He has been an invited speaker of number of conferences and has published more than 100 research articles in reputed international journals of software engineering and computer sciences.