

Intelligent Analysis Method in Safety Science—Space Fault Tree and Factor Space [†]

Tiejun Cui ^{1,*} and Shasha Li ²¹ College of Safety Science and Engineering, Liaoning Technical University, Huludao 125105, China² School of Business Administration, Liaoning Technical University, Huludao 125105, China; lsslntu@163.com

* Correspondence: ctj.159@163.com

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Abstract: The development of the basic theory of safety science is relatively short compared with other disciplines, and the corresponding basic theory is weaker. However, with the development of science and technology, more and more complex systems have emerged. These systems are significantly different from earlier systems, including in complexity, factor changes, data information, and system control. Traditional reliability and fault analysis methods are difficult to solve. In order to manage these problems, the author proposes a space fault tree theory to study system reliability and system fault evolution process. At present, the space fault tree theory is divided into four parts, the space fault tree theory foundation, the intelligent space fault tree, the space fault network, the system motion space and the system mapping theory. The space fault tree is combined with factor space, a cloud model, fuzzy structure element, and system stability and information ecology methodology. The objective is for the space fault tree theory to complete the system reliability and fault analysis, as well as fault big data analysis, fault logic relationship reasoning, system fault evolution process research and system motion change measurement capability. In order to demonstrate the results of the space fault tree research, this paper is written to briefly introduce the four major parts and main contents and results of the space fault tree theory.



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1. Introduction

According to Evolutionary Systems Theory, the emergence of existential risks signifies an evolutionary crisis of complex systems. Those crises are caused by an environment more complex than the options of the systems are. If the organizational relations of the systems undergo a qualitative change, they can help the systems manage with the complexity of their environment (the environment might be external or internal). Such a change transforms the systems into elements of a metasystem or supra-system that represents a complexity gain from which they benefit.

In the 1950s, developed countries vigorously developed weapons equipment and aerospace fields in a special international environment. These fields involved almost all disciplines at that time, consumed immense manpower, financial and material resources, and as a result, became extremely important man-made systems, which were significantly more complex and costly than previous systems. The increase in complexity makes it difficult to analyze and determine the reliability of the systems. The cost of manpower, financial and material resources determine that the system cannot be a fault and reliability reduction. The contradiction is the starting point of system reliability research and the starting point of the entire system engineering, since the reliability and fault analysis methods in system engineering are the same as the original intention of safety science to guarantee system safety. Therefore, the reliability-related theories of system engineering

were introduced into safety science to form the subject of safety system engineering. Taking more than half a century, the development of safety system engineering was slow, which basically continued the traditional safety system engineering methods. However, with the advent of information science, intelligent science, and the era of big data, the system has undergone profound changes, and the application of classical reliability analysis methods is difficult.

With the development of system reliability and fault analysis methods in safety system engineering, the ability to analyze system reliability under the condition of relatively simple, low system complexity and limited data scale has been developed. However, it will be very difficult to use the existing methods for the systems developed in the next 10 or 20 years, when faced with a complex data environment, huge system complexity, intelligent external environment, and more importantly, the challenge brought by the change of the interaction mode between different parts of the system. The internal interaction of the traditional system is the interaction of the physical components. Nowadays, the system generally operates at the level of software, and the future system will have to content with an interaction of the digital information and the signal. Our current approach is at the level of physical component interaction.

With the development of big data technology, intelligent science, systems science and related mathematical theories, current and future safety sciences, especially the reliability and fault analysis methods of safety system engineering must at least meet the ability requirements of fault handling by big data, reliability causality, reliability stability, reliability reverse engineering, and reliability change process description, etc. At the same time, the existing system reliability analysis methods are more specialized for certain systems used in specific fields. Although the analysis results are good, there is a lack of system-level abstraction, which is difficult to meet the requirements of versatility scalability and adaptability. There is therefore a need for a system reliability and fault analysis method that has the above capabilities and meets future system requirements. Therefore, the combination of system reliability analysis methods, intelligent science and big data technology is inevitable and necessary.

In 2012, the space fault tree theory was proposed by the author to study the reliability of the system under the influence of multiple factors. With the deepening of research and the combination of the theory of factor space and other theories, an intelligent space fault tree has been formed. It has been found that the system fault process is a complex network structure composed of many events, and the space fault network is proposed to study the fault evolution process of the system. The system changes differently when various factors are acting and produces different data. Therefore, the space of system motion and the theory of system mapping are proposed to describe the system motion and structure. These are the results of combining system reliability and fault research methods in safety science with intelligence and big data science. Therefore, this paper will focus on research and results.

2. Space Fault Tree Basic Theory

There are two kinds of analysis methods of fault tree, from top to base and from base to top. No matter which method is adopted, the occurrence probability of the top event is expressed by the structural relationship between the basic event and the tree. For a completed system, its structure generally does not change, and the decisive factor that affects system reliability is the reliability of the basic components. The probability of the occurrence of the basic event of the classical accident tree is a fixed value, which leads to the system fault probability, whereby the probability importance and critical importance calculated by it are all fixed values. In this way, the accident tree constructed is only true under a certain condition; at the same time, the traditional accident tree also cannot analyze the impact of changes in these basic events on the system. In brief, the system structure formed by the traditional accident tree is single and invariable, and not easily convertible

into a mathematical model, after which a mathematical method is used to carry on the analysis.

In fact, there are many factors influencing the occurrence of basic events in the system. For example, a diode in an electrical system, its fault probability is directly related to the length of the working time, the size of the working temperature, the current and the voltage, etc. [1]. If the system is analyzed, the working time of each component and the temperature at which the work is adapted may be different. As the overall working time of the system and the ambient temperature change, the probability of fault of the system is also different.

In order to study the influence of system operating environment factors on system reliability, the space fault tree theory is proposed. It is considered that the system works in the environment. Since the physical components or event characteristics of the constituent systems vary with factors, the reliability of the system composed of these components or events is more complicated under the influence of different factors. This is the first stage of the space fault tree theory research, i.e., studying the characteristics of system reliability changes under the influence of multiple factors.

3. Intelligent Space Fault Tree

In further research, the premise of determining the relationship between reliability and influencing factors is the effective processing of fault data. At present, the amount of fault data of the system is large, and the conventional method is difficult to adapt to fault-data processing the large data. Additionally, using the data-processing method, it is also difficult to meet the needs of fault data processing in the field of safety science and system engineering. With the help of the cloud model, factor space and system stability theory, the intelligent reconstruction of space fault tree is carried out.

4. Space Fault Network

Whether in the occurrence of a natural disaster or a fault of an artificial system, it is not a one-step process, but an evolutionary process. Its macroscopic performance depends on the combination of many events following a certain order, and the micro is the interaction between events, which is generally presented as a network connection of many events [2–5]. Here, a natural system refers to a system that respects the laws of nature and is not artificial. The natural disasters that effect the production the life, such as rockburst, landslides, etc., are considered. An artificial system refers to the man-made system that respects the laws of nature according to a certain purpose. The fault refers to a decline or fault in the ability to achieve the purpose of the system that affects people's production and life. Due to the differences in influencing factors, fault data and evolution process, SFEP of all kinds of natural system disasters and artificial system faults has diversity, but it lacks the abstract analysis methods and universal process at the system level, which brings great difficulties to research and prevention. In order to solve the problems of description, analysis and intervention of SFEP, a space fault network is proposed based on the previous research as the third stage of the development of space fault tree theory.

5. System Movement Space and System Mapping Theory

In the space fault tree theory, system reliability or fault evolution is not static, but a changing process. If a system reliability or safety change is abstracted as a system motion, how can we then study the motion of the system? Here, the movement of the system refers to the changes in the systems form, behavior, structure, performance and so on, when the system is stimulated. Before studying the system movement, the following problems need to be solved: how to describe the change in the system, the dynamic force of the change of the system, the performance of the change of the system, measuring change in the system. These issues are the most fundamental issues in the study of systemic movements, and their solutions cover a wide range of fields, including safety science, intelligent science, big data science, systems science, and information science and so on. Based on the factor space theory and the methodology of information ecology put forward by Professor Wang

Pei Zhuang and Professor Zhong Yi Xin, respectively, combined with the space fault tree theory proposed by the author, the description and measurement of system motion are preliminarily realized, namely system motion space and system mapping theory. It has been studied in the field of system reliability research in safety science.

6. Conclusions

The existing research results of the space fault tree proposed by the author are reviewed in this paper. The research process is divided into four stages, including the basic theory of space fault tree, intelligent space fault tree, space fault network, system motion space and system mapping theory. The research involves the fields of safety science, intelligence science, system science, data science, information science and so on. In particular, some methods and theories such as factor space, cloud model, fuzzy mathematics, and information ecology methodology are introduced, which finally makes the contribution to the development of the basic theory of safety science. They provide a basic theory and method for system reliability and fault evolution process analysis under current and future intelligent and data environments.

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