Research Progress of Artificial Immune Systems in Enterprise Risk Management

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Abstract. Businesses were exposed to a wide variety of risks of varying degrees of severity by today's fast-paced changes. How to cope with and avoid these risks has always been a matter of discussion. Scholars have now combined the artificial immune system in immunology with enterprise risk management. Many models have been developed, too. This article conducts a comprehensive and systematic analysis of the development principles and related applications of these models. After the analysis of this article, it is found that artificial immune systems have been applied to varying degrees in enterprises in different fields, such as logistics and finance, petrochemicals, the Internet, etc., showing great potential application prospects. This article aims to discuss enterprise risk response and avoidance based on a deep understanding of artificial immune systems. At the same time, it points out the three shortcomings of the existing related research, namely insufficient cases, lack of interdisciplinary integration and data complexity. This paper puts forward the suggestions and prospects for the future research by coordinating the cooperation within the enterprise and combining the methods of organisational behaviour, artificial intelligence, big data and so on.

Keywords: Immune system, artificial immune system, risk identification, negative algorithm.

1. Introduction

Along with the worldwide economic growth and the increasing development of modern technology, companies use a wide range of measures for risk management. Major accidents, such as logistics safety, and financial turmoil have posed a number of risks to major corporations. For example, a particularly major collapse accident happened on February 22, 2023, in the coal mine of Xinjing Coal Co. Ltd. in Alashan, Inner Mongolia, China, resulting in 53 deaths, 6 injuries, and direct economic losses of 204,325,000 yuan [1]. On 08 December 2023, the General Office of the China's State Council issued the "Opinions of the State Council on Further Improving the Quality of Listed Companies," which urged listed companies and companies to be listed to improve internal governance and carry out internal control evaluations by hiring accounting firms to implement internal control audits of financial reporting. This document uses such approach to help companies to enhance their risk-resistant capabilities [2].

Immunology is an independent and cutting-edge discipline that studies the composition, function and structure of the immune system. The immune system produces complex responses to pathogens or abnormal exogenous stimuli for the purpose of ensuring the safety and health of the host [3]. Only under normal conditions when the immune system interacts to maintain a relative balance, the organism can maintain normal survival. If the body is out of immunopathological changes, then it must be caused by abnormalities in immune function. Because the enterprise in the face of risk is similar to the immune system in to face of the antigen or imbalance state, many scholars from the model based on artificial immune system to explore its application to enterprise risk. Since the 1970s, the artificial immune system has gradually come into everyone's view. Matloobi SM [4] et al. identified the extent of cavitation damage to centrifugal pumps by vibration and current signals, and they compared the artificial immune system with nonlinear support vector machines, multilayer artificial neural networks, K-means, and fuzzy C-means. These people concluded that the features selected by using the artificial immune system have a high degree of accuracy and excellent screening features. Wang, Wei [5] et al. presented a novel complex artificial immune system that introduces complex data and weights, allowing this new system to use complex biased autocorrelation

coefficients of input antigens as antigenic representations. The innovative artificial immune system adds complex pattern recognition capabilities with complex memory and classification capabilities. Jun-qing Li [6] et al. not only proposed six mutation methods to finish the search task in various search spaces with affinity computation heuristic, but also employed a novel population diversity approach to eliminate crowding degree values. Finally, the improved AIS algorithm can search optimal solutions to specific problems. Artificial immune system is currently widely used in many fields, such as security platform construction, association classification [7] and link prediction [8]. Given that enterprises are in a complex and non-static space of people, equipment and supervision, it is crucial to put immune systems into security risk management [9]. However, artificial immune systems are still in their infancy for safety risk management in specific enterprises.

The artificial immune system has great application prospects in specific enterprise risk management, but they are currently under-researched and in their infancy. Therefore, this paper analyses and discusses three perspectives of risk identification, self and non-self distinction, and risk response, aiming to accurately reflect the specific algorithms and development trends in this field through systematic and comprehensive analysis, as a way to avoid duplication of research by future researchers. It also provides theoretical support and research methods to help scholars identify problems and gaps in existing research.

2. Fundamentals of Immunology and the Artificial Immune System

Immunology is the science of studying the structure and function of the immune system of biological organisms, which includes immune memory, biological immune system, immune recognition and immune regulation, and other immune responses against external invasion [10]. In addition, immune organs are biological tissues with immune functions. The central and peripheral immune organs play the roles of cell growth and differentiation and provide sites for immune responses, respectively. Figure 1 demonstrates some cell types after the differentiation of primitive cells. Lymphocytes are the main component of immune organs, distributed throughout the body, and each organ plays its own unique character, such as the place for cell differentiation [11].

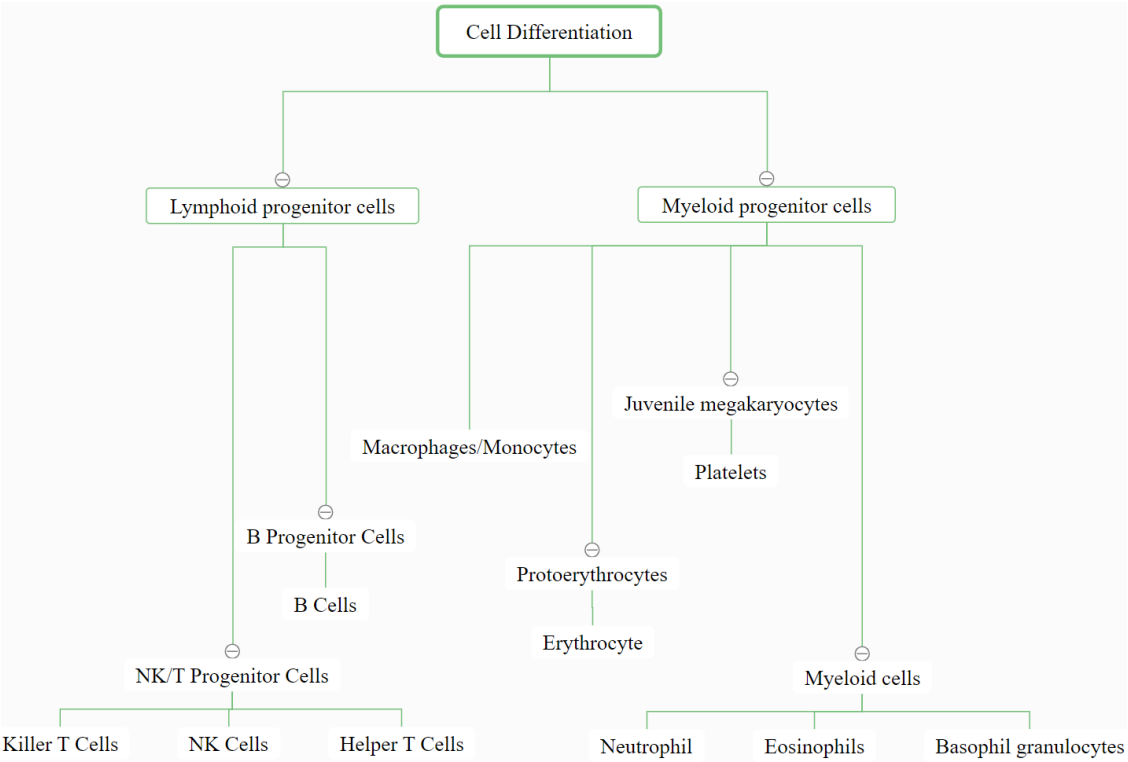

Figure 1. Cell differentiation diagram

Artificial immune system is a system built on the basis of biological immune system using biomimetic technology [12], which has the characteristics of learning, memory, self-organisation and self-adaptation [13]. It can take advantage of the powerful self-adaptation, evolution, diversity, learning memory, robustness, imperfect matching, and distribution of the biological immune system (Table 1) to refine a diverse information processing mechanism. Based on artificial immune systems, scientists can develop various types of information processing technologies, computational technologies, engineering and scientific intelligent systems [11, 14].

Table 1. Characteristics of the biological immune system

Peculiarity	Concept elaboration
Self-adaptation	The immune system can change and improve in response to changes in the environment
Evolutionary	Antibodies evolve as the characteristics of the antigen change
Diversity	The immune system is able to select and match effective antigens to multiple antigens
Learning Memory	An initial response to the first invasion of an antigen and a secondary response to a second invasion
Robustness	Problems with individual systems in the immune system are not catastrophic to the entire system
Imperfect match	Individual antibodies that do not match perfectly can match multiple antigens by binding to each other
Distributed	The immune system consists of multiple units that interact with each other

From an immune-based perspective, artificial immune systems depend on large quantities of algorithms to work. These can be classified into four categories: immune learning, immune memory, clonal selection, and immunogenetics (Figure 2). Immune learning is the process of continuously recognising antigens such as bacteria and viruses that enter the organism. This allows the immune system to respond faster and produce sufficient antibodies to antigens that it meets repeatedly. Immune memory is categorised into transient, short-term and long-term memory, which helps the system store information. Clonal selection has self-organising, self-adaptive and self-learning properties, such characteristics help the system to select global optimisation solutions to deal with the problem more broadly. Immunogenetics is the incorporation of genetic factors in immunological algorithms, which improves the recognition and search speed of the system [11].

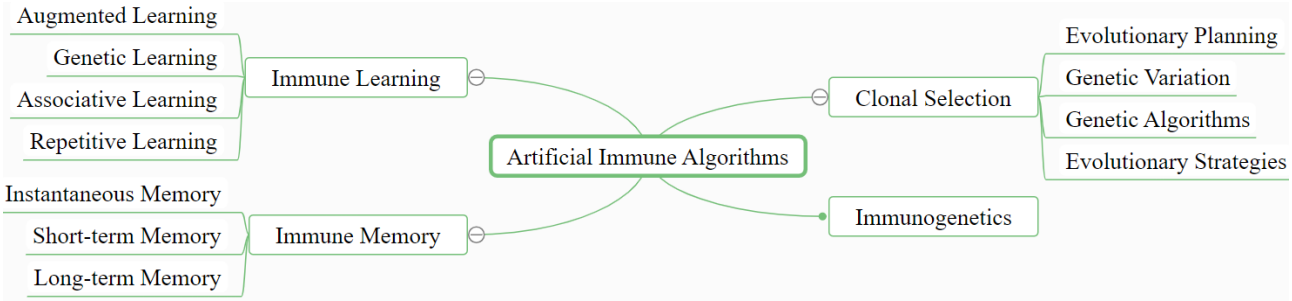

Figure 2. Mind map of artificial immunity algorithm

3. Application of Artificial Immune Systems in Enterprise Risk Management

3.1. Risk Identification

In the biological immune system, there is an interaction and mutual assistance between the innate immune system and the adaptive immune system. The principle of risk identification based on artificial immune systems is similar to the coordination between these systems. For example, innate immune cells recognise their own state and activate lymphocytes, which activate the adaptive immune system to react to antigens and produce antibodies. In the artificial immunity-based logistics financial

risk identification model (Figure 3) proposed by Xingyu Zhang [11], he proposed that when abnormal data (antigen) enters into the logistics system, it triggers the identification and comparison of the anticipatory risk pool (innate immune cells). On the other hand, if the abnormal data is not risky, it triggers the T-cell learning module (adaptive immune response) and the forecasting module and finally puts into the memory risk pool (antibody production) so that the enterprise can react quickly. If the anomalous data is risky, it will go directly to the alarm module to issue a warning. After establishing the risk identification model, seven more important attributes are selected for simulation training. The test concludes that the artificial immune risk identification mode, compared with the traditional negative algorithm recognition model, improves the average detection rate (88.9%→96.6%), reduces the average false alarm rate (14.56%→7.74%), reduces the training time (2.36s→1.23s), and reduces the average testing time (7.56s→5.65s) and other aspects have been significantly improved. At the same time, through the simulation test to analyse the impact of 450 different factors on the risk level, three main risk factors affecting the development of logistics finance are identified: operational risk, pledge risk, and regulatory risk, all of which will have a greater impact on the risk identification ability of financial logistics. For this reason, he proposes contract audit management, standardisation of logistics documents, business inspection and other measures to mitigate the impact of operational risk on financial logistics enterprises. Secondly, enterprises should reasonably select stable pledges in the market, provide standardised warehouses, and strictly implement standardised operations to cope with the risks of the pledges themselves. Finally, he suggests that enterprises build an internal information platform as a way to clarify the division of labour among personnel and supervise each other to ensure good management of regulatory risks. This is valuable for logistics enterprises to reduce the impact of logistics financial risks and losses and ensure the sustainable development of the logistics financial industry.

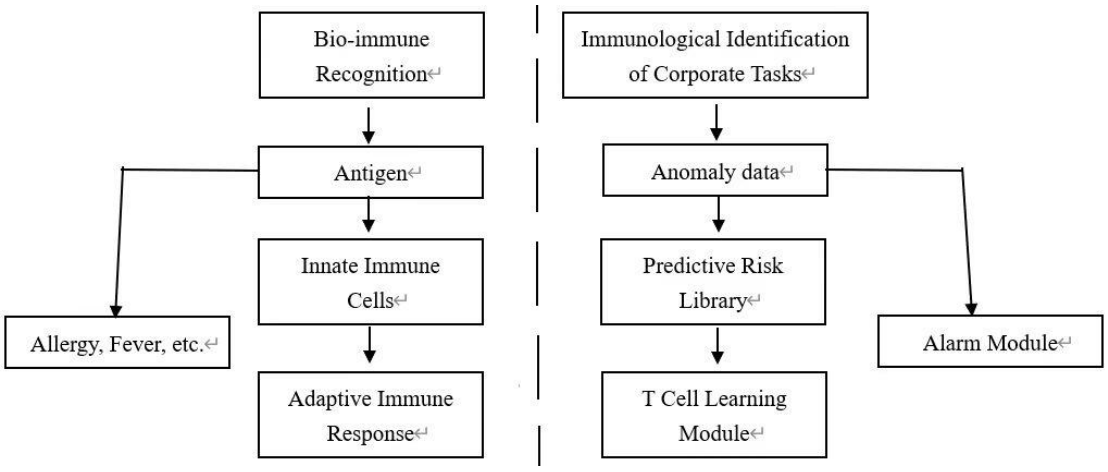

Figure 3. Immunological perspective of the enterprise risk identification process

3.2. The Distinction between Self and Not-self

Artificial immune system can define the self (machine normal state) and not-self (machine fault state) in enterprise production safety based on the negative selection algorithm for monitoring and fault diagnosis for enterprise production safety [14-15]. Negative selection algorithms are algorithms imitated from the mechanisms of self and non-self in immune system identification. It focuses on the process of generating a large number of random detectors first, then screening these generated detectors against the self for fitness, leaving behind the non-self detectors, and finally leaving behind a sufficient number of mature detectors [14]. In 2011, the negative selection algorithm was improved by someone [15], who observed and compared and analysed the PCA (principal component analysis) and Vorono detector-based negative selection algorithms on three typical petrochemical company production process fault cases. They found that the latter was able to improve the overall identification of faults than the former by at least 18% and decrease the false alarm rate by 0.8%. What's more it also improves the overall recognition rate by at most 40% and reduce the false alarm rate by 2%. This

shows that the negation selection algorithm based on Vorono detector can greatly improve the accuracy of fault monitoring and diagnosis. Nowadays, scholars [16] have used a V-Detector-KN algorithm, which uses known non-self to fix vulnerabilities where the performance of the classic negation selection algorithm is degraded, thus reducing the randomness and blindness of vulnerability fixes. Ayodele Lasisi and Ali M. Aseere [17] proposed nature-inspired meta-heuristic cuckoo search (CS). This kind of method used stochastic global search algorithm to improves the random generation of detectors in NSA (Negative Selection Algorithm). As a result, this approach progressed an average improvement of around 3.5% in the detection rate. These improvements to the negative selection algorithm can lead to better integration of the immune system, which can help petrochemical and other production enterprises to supervise and accurately identify the state of the machines in the production process in the case of great increasing numbers and types of machines in the production of enterprises nowadays. In the face of complex production processes, enterprises can collect more complete data to ensure that the characteristics of the data are not lost, and thus achieve the purpose of optimising production equipment and production processes.

3.3. Risk Response

Enterprises can streamline their organisational operations and processes by process mining of event schedules to satisfy customer needs, and then rationally analyse their own operations, and perform data risk analysis. Yang Xu [18] and others proposed HAIA (Hybrid Artificial Immune Algorithm), which based on the clonal selection of artificial immune system. HAIA mainly ensures matching of time and number by constructing the affinity function in the artificial immune evolutionary algorithm. At the same time it introduces the annealing mechanism to solve the log fusion problem of one-to-many, many-to-one or many-to-many. Xu Yang et al. conducted comparison experiments and many-to-many relationship experiments on the two algorithms of HAIA and AIA (Artificial Immune Algorithm). These two experiments are in the context of IT event management process and operation and maintenance task management process supported by a simplified IT operation and maintenance SaaS application platform of an enterprise. The results tell us that: in the comparison experiments, although HAIA has only a small advantage over AIA in terms of fusion success rate, the significantly fewer evolutionary generations of HAIA (about 3000 fewer generations) lead to the fact that HAIA can perform tasks faster. Second, in the many-to-many relationship experiments, HAIA is able to better achieve log fusion containing many-to-many matching relationships. This algorithm, which can quickly search, match, maintain information integrity and integrate complex logs, can help enterprises better identify process problems and find matching optimisation solutions to ensure the effectiveness and sustainability of the solutions. At the same time, HAIA can help enterprises to rationally analyse process operations and data risks, so that they can better respond to market challenges, satisfy the needs of the customers, and pick out the target customers that match the company's needs.

4. Discussion and Outlook

Through the previous analyses, it can be seen that AIS (Artificial Immune System) provides a new perspective on enterprise risk management. Drawing on the principle of the immune system, companies can identify and respond to risks more effectively, thereby reducing the impact of risks on business operations. However, there are still some challenges and problems in the research and application of this field.

Firstly, the application of artificial immune system in enterprise risk management is still in the exploratory stage, and more empirical studies are needed to verify its effect. In the future, the effectiveness of artificial immune systems in risk identification and response in different types and sizes of enterprises can be explored in depth through case studies and other methods. In addition, the implementation of enterprise risk management requires the cooperation of many parties, including management, employees, consultants and so on. How to coordinate the interests and objectives of all

parties in an enterprise to ensure the effective implementation of risk management measures and to strengthen the links between organisations in different departments are also issues of concern.

Second, the integration of artificial immune systems with enterprise risk response requires interdisciplinary collaboration. While algorithms such as negative selection algorithms and immune evolution algorithms, which belong to the fields of mathematics, computers, and medicine, have been combined with AIS to provide organisations with new tools to cope with risk. However, there is a need for further research and exploration of the possibilities of combining AIS with other fields such as blockchain and artificial intelligence. In addition, how these methods can be combined with other risk management tools and approaches to further improve the effectiveness of risk response is also a focus of future research. In the future, it is possible to combine the theories and practices of multiple disciplines, such as immunology, risk management, and organisational behaviour, through interdisciplinary research teams, to jointly promote the development of enterprise risk management.

Finally, the many and complicated data in enterprises also hinder the development of artificial immune systems in the field of enterprise identification and response to risks. With the development of technology and the accumulation of data, models for enterprise risk management can be further optimised in the future by using technological tools such as big data and artificial intelligence. For example, deep learning technology can be used to process and analyse a large amount of data, effectively deal with multiple variables, prevent information loss, and improve the accuracy of fault diagnosis; at the same time, data mining technology can be used to real-time monitoring and early warning in enterprise's operational data, so as to improve the accuracy of risk management.

5. Conclusion

In conclusion, artificial immune system has emerged as a successful model for subsequent research in risk identification and response for different types of companies (logistics and finance companies, petrochemical companies, internet companies). The risk identification model based on artificial immune system has the timeliness and flexibility beyond the traditional one, but still has nearly 10% false alarm rate, which needs to be solved by scholars by combining more factors to build the model. Negative selection algorithm can be combined with Vorono detector, cuckoo search algorithm, V-Detector-KN algorithm and other ways to improve. These algorithms can help the artificial immune system reduce the randomness of the training, improve the global search. Because the current negative selection algorithm has greater flexibility in the selection of parameters, the optimal parameters for research can be targeted in the future. Hybrid Artificial Immune Algorithm optimises the risk log fusion problem, which retains the integrity of the information while matching the logs quickly, but retains the timeliness of the information poorly, which requires one to study the streaming logs and fuse them. Although this paper fails to provide examples of the ability of artificial immune systems to respond to and identify risks in all types of companies, and enumerate the full range of algorithms in AIS, it is the flexible adaptability of immunology that its application in enterprise risk management has a great deal of promise and potential. With the increase of case studies, the combination of artificial intelligence, and the optimisation of data processing techniques such as deep learning, AIS will surely provide more powerful tools for research in the field of enterprise risk management.

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