CURRENT SITUATION AND PROSPECT OF COMPUTER AIDED BIONIC DESIGN

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Introduction. As an interdisciplinary subject, bionics provides new ideas, principles and theories for scientific and technological innovation, and is an important tool for innovation [1,2]. It focuses on the application of "biomorphology, structure-function, color composition, and texture intention" [3,4], and emphasizes the inspiration from the structure, function, processes, and mechanisms of living organisms that adapt to their environment to create innovative designs for sustainable social development [5,6]. With the advent of the era of the fourth industrial revolution, bionics has received worldwide attention, and the market scale it relies on is expected to expand [7]. Bionics has gradually developed into a new interdisciplinary discipline based on the interpenetration and integration of multiple disciplines under the demand of modern intelligent manufacturing [8]. Entering the information age, bionics is more closely connected with frontier technologies. With the rapid development of computer technology and the trend of intelligent product innovation, the market has put forward higher requirements for innovative products in various fields, and human beings have begun to explore the bionic field at a deeper level [9]. Under the trend of efficient automation, the single use of traditional bionic design methods can no longer meet the innovation needs. A variety of software implementations, programming languages and technologies have emerged in the software industry [10]. Computer technology is gradually applied to bionic design. With the attempts of scholars, computer aided bionic design innovation has achieved remarkable results and has been used as a common innovation method in various fields. In order to increase the application scope of computer aided bionic design and increase the possibility of innovation and integration in various fields. This paper summarizes the relevant literature and practical hotspots of computer aided bionic design in the past ten years, analyzes the existing problems and puts forward reasonable suggestions to help scholars of various disciplines understand the advantages and functions of computer-aided bionic design, so as to guide the innovative design and development in various fields. It mainly focuses on the following three aspects: 1. Current situation of computer-aided bionic design; 2. Problems in computer-aided bionic design; 3. Analysis of hot spots and trends of computer-aided bionic design.

Concept and application direction of computer aided technology. Computer aided technology refers to the methods and techniques that use computers as tools to assist people in completing tasks in specific application fields [11]. It mainly

includes: CAD (Computer Aided Technology); CAPP (Computer Aided Process Planning); CAE (Computer Aided Engineering); CAM (Computer Aided Manufacturing); CAQ (Computer Aided Quality); CAT (Computer Aided Test); and CAM (Computer Integrated Manufacturing) [12]. The basic concepts and application directions of computer aided technology are shown in Table 1.

The name of computer aided technology	Basic concept	Application direction
CAD (Computer Aided Technology)	The use of computers to assist in the development, modification, study, or optimization of designs is known as computer aided design (CAD) [13,14].	CAD models are widely used in manufacturing, and are gradually being used in architecture, architecture, fashion, and many other industries [15].
CAPP (Computer Aided Process Planning)	With the help of computer hardware and software technology and supporting environment, the numerical calculation, logical judgment and reasoning functions of the computer are used to develop the machining process of parts [16].	The system is used to assist manufacturing engineers in product structural manufacturability inspection and product process design [17].
CAE (Computer Aided Engineering)	Computer aided engineering (CAE) is the use of computer software to simulate the physical phenomena that occur in engineering work [18,19].	CAE has become an indispensable numerical calculation tool in engineering and product structure analysis (such as aviation, aerospace, machinery, civil structure and other fields). It is an important means to analyze various problems of continuum mechanics.
CAM (Computer Aided Manufacturing)	Using computer aided technology to complete the whole design activities from production preparation to product manufacturing.	Mainly used in manufacturing, linked to manufacturing processes and production equipment [20].
CAQ (Computer Aided Quality)	Enterprises use computer aided quality assurance and management activities [21].	Computer aided quality management (CAQ) is the focus of the R&D process for companies developing and implementing advanced manufacturing technologies.
CAT (Computer Aided Test)	It refers to a method that uses computer assistance for testing [22].	Computer aided testing can be used in different fields, mostly in the mechanical industry [23].
CIM (Computer Integrated Manufacturing)	The CIM concept helps manufacturing systems to take advantage of computerized systems and their integrated applications in manufacturing environments [24].	Using computer technology in manufacturing production process and system structure, is a means of enterprise management operation.

Fig.1 Concept and Application Direction of Computer Aided Technology

Computer technology applied to assist bionic design. In recent years, computer-based graphics knowledge has developed and become the most common trend. Designers usually use computer aided design to generate design concepts and draft documents. Computer aided manufacturing (CAM), computer aided design (CAD), computer related algorithms, and other computer technology support have become beneficial tools to assist designers and engineers in producing goods [25-27]. In response to the development of the times, scholars have started to try to apply computer aided technologies to guide bionic design and apply natural biological advantages to innovative practices in more fields. For example, Li et al. used computer 3D printing technology to build a bionic folding wing and tested its folding and unfolding performance [28]; Jia et al. used theoretical analysis, computer simulation, and design-expert software to determine the optimal combination of parameters and test it software to determine the optimal combination of parameters and experimentally optimize the design to complete the design of an intelligent forelimb discharger for a bionic mole rat [29]; Zhong et al. proposed a structural topology optimization method combining bone remodeling algorithm and practical engineering requirements based on bionic principles using MATLAB and ANSYS joint simulation [30].

From the above research, it can be seen that computer aided bionic design has achieved significant results in many fields, such as creating structures with better mechanical performance, proposing new research methods, and optimizing and verifying existing designs to improve efficiency, etc. However, no scholars have done a systematic review of computer-aided bionic design, so it is difficult to form a complete and standardized scientific design method for the reference of academia and enterprises. Therefore, this paper will further analyze the current situation, research

focus and trend of computer aided bionic design to provide reference for enterprise innovation.

Current situation of computer aided bionic design. Since the 21st century, the trend of computer aided bionic design research has attracted the majority of researchers to explore and apply, and achieved remarkable results [31]. To some extent, it has been verified that computer technology is an effective tool as a guide for bionic design applications and has helped to develop innovations and research methods in various fields. For example, students from ICD, ITKE and the University of Stuttgart explored the translation of the biological principles of sea urchin plate skeleton morphology in architecture through computer design simulation and computer controlled manufacturing methods; Li et al. built the framework of information security active defense system of digital twin system based on bionic knowledge and digital twin technology to improve industrial information security defense capability [32]; Zhu team of Beijing Institute of Fashion used wall surface as a carrier, based on computer programming technology to imitate the rhythm of deep sea creatures when they breathe, and changed the exposed area of noise-reducing base material through the technique of airbag deformation, thus regulating influence the sound absorption capacity of the noise reduction materials and achieve the effect of indoor sound regulation. It is not difficult to see that the application of computer aided bionic design has made some progress, and there are new explorations in many fields such as materials, machinery, architecture, and computers.

Hot research fields and technical achievements. Through collecting and sorting out the literature related to computer aided bionic design at home and abroad in the past ten years, it is found that the application hotspot areas mainly contain mechanical robotics, material development, product design and so on.

In order to broaden the road of computer bionic applications, this paper summarizes the main application technologies and existing achievements in each hot field, as shown in Fig.2. It is found that MATLAB and simulation software are mainly used to establish dynamic models and upgrade and mechanical structures in the field of robotics. In the field of material development, computer simulation and rapid printing are mainly used to construct models with excellent performance. In the field of product design, MATLAB and parametric modeling are mainly used to improve product performance and provide customized products.

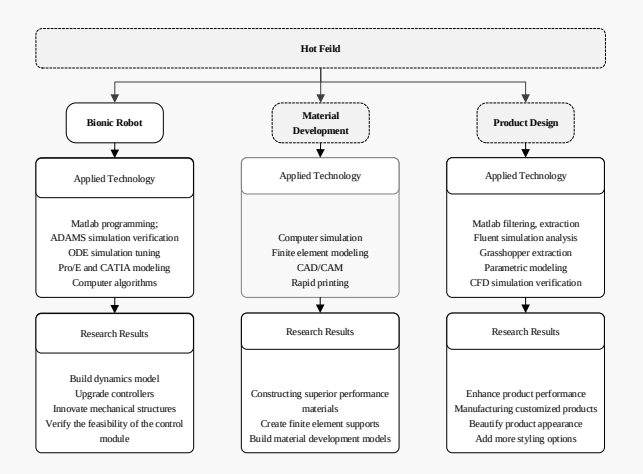

Fig.2 Hot research fields, application technologies and research achievements of computer bionic design

Research focus on computer-aided bionic design. By sorting out the hot application fields of computer aided bionic design, the main technologies of computer aided bionic design and the existing achievements in each field are clarified. In order to explore the research focus of computer technology aided bionic design, clarify the research ideas and master the related technologies, this paper also analyzes the research focus and methods of computer aided bionic design, and finds that computer technology for bionic design is mainly focused on four aspects: auxiliary bionic form extraction and processing, bionic structure establishment and modification, biological color extraction and application, and bionic design post-optimization as shown in Fig.3.

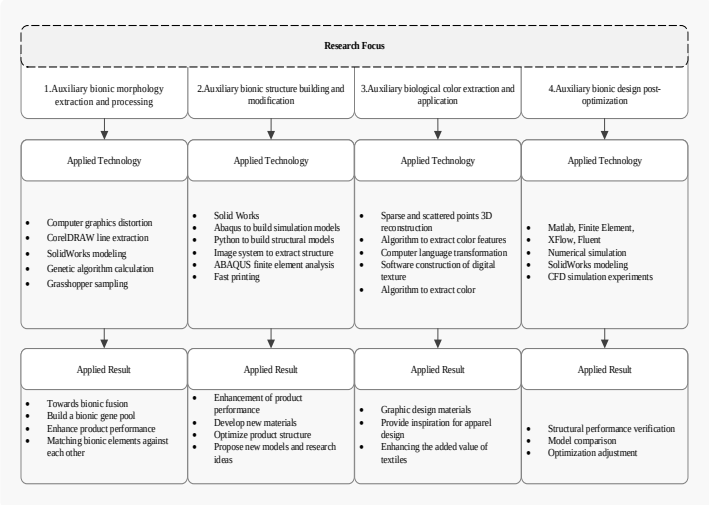

Fig.3 Key Points of Computer Aided Bionic Design

Problems in computer aided bionic design. At present, computer aided bionic design has not formed a set of systematic methods with certain inapplicability. The main reason lies in the application field is not comprehensive, lack of norms, research methods homogeneity and other aspects of the problem.

Applicability in various fields is difficult to prove. By combing and analyzing the current application field of computer aided bionic design, it is found that computer aided bionic design is a breakthrough interdisciplinary attempt in the 21st century, but there are still some doubts about the research methods. The main reasons are as follows: first, there is a lack of practical cases. At present, various scholars mainly conduct simulation testing and modification through computer software, and lack ground test and production application, so it is difficult to support the feasibility of this research method. Second, there are few research results in other fields. In addition to the relevant research of hot subjects, other disciplines are still in the exploratory stage. There are few existing studies and no outstanding landmark achievements. It is still a long way to explore the applicability and limitations of computer aided bionic design. Third, the lack of comparative verification. Although various scholars try to infer that the results obtained by computer-aided bionic design method are better through comparative experiments, as a research method, there is a lack of horizontal comparison, and few scholars try to compare the research results with

other methods, so it is difficult to explain the advantages of this method and it is not convincing.

Lack of unified standards and objectivity. The lack of unified standards and objectivity of computer aided bionic design mainly stems from the following two aspects: On the one hand: the advantages and disadvantages of the application of technology are unclear. Through the investigation and summary of the application technology, it is found that a variety of computer software assisted bionic design can achieve the same purpose. Scholars often choose the corresponding technology according to their own habits, which lacks some objectivity. At present, there is no complete summary of the advantages and disadvantages of various software, leading to no norms and standards in the innovation of computer-aided bionic design.

On the other hand, the rationality of application of bionic elements lacks certain objectivity. Especially in the case of morphological bionics, although computer technology can extract biological forms and optimize lines very well, the cognitive gap between users and designers is gradually shortened through the constructed model [33]. However, in the process of application, the matching degree mostly depends on the designer's aesthetic and subjective consciousness judgment, which is easy to appear unreasonable application and poor effect.

The homogenization of research methods is serious. At present, this method can quickly provide support for the establishment, optimization and modification of bionic elements by applying the advantages of computer software to assist bionic design. The application mainly focuses on two-dimensional plane drawing, three-dimensional convenient modeling and finite element analysis, which provides great convenience for innovation in various fields. However, too much focus on the application of software, only the pursuit of rapid processing of biological elements, the limited software function leads to the basic consistency of research methods in various fields, the advantages of quantitative analysis gradually evolved into rigid handling plagiarism, homogenization is serious, not conducive to the development of new ways of innovation.

Research Development Trends. At present, with the improvement of computer aided bionic design, this method has been gradually applied in many fields such as computer, material, product design and so on. The discussion on computer aided bionic design can be carried out from the following aspects:

(1) Adapt to the trend of the times and apply to the design of products suitable for aging. Based on the research results of existing robots, we can apply computer aided bionic design to service robots. Such as Ihamaki, Zhang,Xiaodong, Zhang Wanyu and other scholars have started to study bionic robots serving the elderly [34-36], using science and technology to serve the elderly, paying attention to the economic development of the elderly enabled by science and technology, and making contributions to the physical and mental health of the elderly and their better integration into society. It will be a very promising attempt to apply interdisciplinary methods to the research of hot topics.

(2) Realize effective mapping of product modeling and biological elements. At

present, computers can well realize the extraction and processing of biological features. In the application of element matching, although some scholars have tried to use computer technology to judge whether the application of elements is accurate, there are still some limitations. In the future, qualitative and quantitative tools can be combined to develop a set of norms for evaluating whether the effective mapping between product modeling and biological elements is realized.

(3) Optimization of computer aided bionic design method. Although the existing methods have created some value, the application technology width and research depth are not enough. In order to broaden the breadth of technology, we should first master the advantages of various computer technologies, and then try to match the technology to the appropriate research of bionic design. At this stage, theories in other fields can be introduced to improve the shortcomings of existing methods, so as to increase the applicability of the method. In order to deepen the research depth, the advantages and disadvantages of applied technologies can be summarized to provide references for scholars in other fields to choose appropriate innovation methods.

Conclusion. Computer aided bionic design is an effective means of modern innovation and a multidisciplinary trend under the incentive mode in the intelligent era. It is very beneficial to the whole process modeling and the overall optimization of the process, and can effectively support the integration of innovation in various fields.

(1) This paper collects the application data of computer aided bionic design in the past ten years, systematically combs and summarizes the hot research fields, research achievements, applied computer technology and research priorities of computer aided bionic design.

(2) At present, there are still many limitations in the application process of computer aided bionic design. Therefore, the reasons are analyzed, such as incomplete application field, lack of norms, homogeneity of research methods, etc., and the problems behind the reasons are analyzed to provide suggestions for future optimization and upgrading.

(3) The development trend of computer-aided bionic design is analyzed, and the exploration idea of broadening the breadth of technology research - combining theories in other fields - extracting biological elements efficiently - realizing the effective mapping between products and elements - verifying the rationality of application and market value - enhancing the practicability is proposed; how to optimize the existing methods, maximize the use of the previous work, and how to provide reference for other scholars are discussed.

Refercences

1. Lu Yong-xiang. Significance and development of bionics [J]. Scientific Chinese, 2004 (04): 22 – 24.
2. Luo Shi-jian, ZHANG Yu-fei, et al. Status and progress of product shape bionic design[J]. Journal of Mechanical Engineering, 2018, 54(21): 138-155.
3. Xu Hui. Application of bionic design in product design[J]. Packaging Engineering, 2017, 38(14):208 – 210.

4. Jiang Mu. Bionic's value in industrial design[J]. Art & Design, 2013(04):16 – 19.
5. BAE H, LEE E. Biological and ecological classification of biomimicry from a biology push standpoint[J]. Ecosphere, 2019, 10(11).
6. MACKINNON R B, OOMEN J, ZARI M P. Promises and Presuppositions of Biomimicry[J]. Biomimetics, 2020, 5(3).
7. C HERWEIJER B C. Innovation for the Earth Harnessing Technological Breakthroughs for People and the Planet[C]. . World Economic Forum, 2017.
8. Ren Lu-quan, Liang Yun-hong. Introduction to bionics[M]. Bei Jing: Science Press, 2016.
9. Li Xiu-juan, Zhang Zhi-hui, Zou Meng, et al. Analysis of the necessity of establishing new bionics discipline and program from the perspective of demand[J]. Research in Higher Education of Engineering. 2019(02):46-49+72.
10. SHIM J P, WARKENTIN M, COURTNEY J F, et al. Past, present, and future of decision support technology[J]. Decision Support Systems, 2002, 33(2):111–126.
11. Gu Xiao, Ni Jun-chao. Research progress of computer aided technologies in plastics industry[J]. China Synthetic Resin and Plastics, 2019, 36(04):91 – 95.
12. [ANONYMOUS]. Computer aided .[J]. Vyber Informaci Z Organizacni a Vypocetni Techniky, 1984(5):613–624.
13. XU X Y, WANG Y Y. Multi-model technology and its application in the integration of CAD/CAM/CAE[J]. Journal of Materials Processing Technology, 2002, 129(1-3):563–567.
14. MEINDERS T, BURCHITZ I A, BONTE M H A, et al. Numerical product design: Springback prediction, compensation and optimization[J]. International Journal of MacHine Tools & Manufacture, 2008, 48(5):499–514.
15. LI W, MAC G, TSOUTSOS N G, et al. Computer aided design (CAD) model search and retrieval using frequency domain file conversion[J]. Additive Manufacturing, 2020, 36.
16. Wang Sheng-ren, Guo Yan, Qiao Xing-hua, et al. Research on assembly process technology based on digital twin[J]. Modular Machine Tool & Automatic Manufacturing Technique, 2021(08):131 – 134.
17. Cui Jia-chao, Wang Ting-jun, Zhang Ke. Data integration for CAD/CAPP/PDM system[J]. Manufacturing Automation, 2019, 41(11):124 – 127.
18. OTARAWANNA S, NGIAMSOONGNIRN K, MALATIP A, et al. An educational software suite for comprehensive learning of Computer-Aided Engineering[J]. Computer Applications in Engineering Education, 2020, 28(5):1083–1109.
19. Fu Rao, Wang Bing-le. Application of CAD/CAE in simulation and optimization for plastic molding[J]. China Synthetic Resin and Plastics, 2020, 37(01):93 – 96.
20. FELDHAUSEN T, HEINRICH L, SALEEBY K, et al. Review of Computer-Aided Manufacturing (CAM) strategies for hybrid directed energy deposition[J]. Additive Manufacturing, 2022, 56.
21. Li Xiang-dong. Computer aided quality management application of CAQ system[J]. Mining & Processing Equipment, 1998(03):77 – 78.
22. Gao Xiao-kang, WALTER STUETZ, JUERGEN ZECH, et al. Computer aided

testing technique and application[J]. Computer Measurement & Control, 2001(05):4-5+38).
23. Guo Shan-guo, Zhang Hua-jin, Wu Qiu-jun, et al. Design of testing system of radial plunger variable pump cat test stanc[J]. Machine Tool & Hydraulics, 2022, 50(03):134 - 137.
24. DELARAM J, VALILAI O F. An architectural view to computer integrated manufacturing systems based on Axiomatic Design Theory[J]. Computers in Industry, 2018, 100:96–114.
25. SHIVEGOWDA M D, BOONYASOPON P, RANGAPPA S M, et al. A review on computer-aided design and manufacturing processes in design and architecture[J]. Archives of Computational Methods in Engineering, 2022.
26. MAY R F. Computer aided design and computer aided manufacturing in the '80s[J]. Aeu, 1982:143–147.
27. WANG X Y, YUE L. [Management and improving the marginal adaptation of chairside computer aided design/computer aided manufacturing restorations][J]. Zhonghua Kou Qiang Yi Xue Za Zhi = Zhonghua Kouqiang Yixue Zazhi = Chinese Journal of Stomatology, 2021, 56(1):57–62.
28. LI X, GUO C, MA Y, et al. Design of bionic foldable wing mimicking the hind wings of the c. buqueti bamboo weevil[J]. Journal of Mechanical Design, 2021, 143(8).
29. JIA H, WANG Q, HUANG D, et al. Design of bionic mole forelimb intelligent row cleaners[J]. International Journal of Agricultural and Biological Engineering, 2019, 12(3):27–35.
30. ZHONG Y, FENG H, WANG R. Application research of a structural topology optimization method based on a bionic principle[J]. Engineering Optimization, 2021, 53(10):1733–1751.
31. ROVALO E, MCCARDLE J, SMITH E, et al. Growing the practice of biomimicry: opportunities for mission-based organisations based on a global survey of practitioners[J]. Technology Analysis & Strategic Management, 2020, 32(1):71–87.
32. Li Lin-li, Gu Fu, Li Hao, et al. Framework and key technologies of digital twin system cyber security under perspective of bionics[J]. Journal of Zhejiang University(Engineering Science), 2022, 56(03):419 - 435.
33. Li Xiong, Su Jian-ning, Chen Yan-hao, et al. Review of product image form design and lts application[J]. Packaging Engineering, 2019, 40(08):1 - 9.
34. IHAMAKI P, HELJAKKA K. Robot pets as "serious toys"- activating social and emotional experiences of elderly people[J]. Information Systems Frontiers, 2021.
35. ZHANG X, MU X, XU H, et al. Vibration characteristics analysis of human-robot coupled system for walking posture of elderly-assistant robot[J]. Ieee Access, 2021, 9:44217–44235.
36. Zhang Wan-Yu, Zhou Chun Yan, Chen Yu. Evaluation on modeling design of elderly service robot with improved Delphi and multi-attribute decision-making[J]. Journal of Machine Design, 2020, 37(10):134 - 138.