Optimization of CAD Information Integration System using Computer Network Design

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Abstract. In this paper, the definition of the finite element model is added to the geometric model based on B-Rep structural representation as an analytical feature, and a parametric CAD network-integrated model containing geometric modeling data and finite element feature attribute data is proposed. And the automatic extraction of the finite element model and the dynamic linkage with the integrated model is realized on the professional CAD platform by using parametric hybrid modeling, automatic finite element meshing, and engineering attribute assignment techniques. On this basis, a framework of CAD information integration and optimization design system integrating design, analysis, evaluation, and optimization functions is constructed. In this paper, a prototype system of optimization design based on a CAD network-integrated model is developed, and the system functions are introduced through application examples to prove the effectiveness and feasibility of the system. The research seamlessly integrates CAD integrated design technology, numerical simulation technology, comprehensive evaluation technology, and optimization design technology with professional CAD platforms, reduces the conversion of models in the design and analysis process, reduces the dependence of design solution evaluation on the experience of technicians, and is of great significance in promoting the automation and intelligence of CAD information integration system.

Keywords: network integration; design optimization; CAD information; computer network
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1 INTRODUCTION

Computer-aided tools have computerized design to a certain extent, but in the process of product design, while generating a large number of documents and drawings, it is necessary to query and make full use of the existing design data many times. The application of CAD technology requires the computer to manage a large number of drawings and technical data effectively, and to be able to query and obtain the required technical information easily and quickly when needed; to be able to query according to the project, designer, work stage, approval status, date, type, and various parameters defined in advance, such as material, weight, processing method, etc. In the query, it is possible to find out not only the current information but also the corresponding information from the past or similar [1]. In addition, the computer is also required to record in detail the original data and the corresponding changes in the design and processing process, and to describe the currently valid data in different versions. The managers of the computer system are required to be able to give different powers to handle different ranges of data according to the different responsibilities held by each type of personnel. Likewise, different confidentiality levels should be set for the data according to the different scopes of application to ensure the security and confidentiality of various types of data. With the development of computer technology and the successful application of CAD technology in enterprises, enterprises feel the importance of information management more and more. Informationization instead of industrialization has become an important direction of modern enterprise development [2]. With the development of the enterprise informatization process, enterprises are using more and more application software.

With the increasing dependence of people's production and life on computer networks, whether computer networks can operate reliably gradually becomes an issue of concern for management and users. Based on the overall situation of potential risks of computer networks, the article fully uses the theory of operation research and system reliability and establishes the corresponding mathematical model in conjunction with the actual situation to discuss the improvement of the reliability of computer networks as a whole, to maximize the availability of computer networks. Integration is not only the interconnection of individual technologies, or the integration of applications as long as they are networked, but also the optimization and reorganization through unified planning and design, analysis of the role, and interrelationship of the original unit system [3]. The integrated system has the advantages of reducing data redundancy, realizing information sharing, facilitating reasonable planning and distribution of data, facilitating scale optimization, facilitating parallel engineering, improving efficiency and effectiveness, and facilitating people to work in coordination with each other. The specific content of system integration generally includes the integration of the operating environment, information integration, functional integration, technical integration, and human and organizational integration. Among them, information integration is the core of system integration [4].

2 RELATED STUDIES

With the increasing maturity and widespread use of computer graphics and interactive technologies, and the development of computer hardware, general-purpose CAD systems based on small machines began to enter the market, while specialized CAD systems for certain specific problems flourished. Another important feature of this period was the development of the 3D geometric modeling software industry and the adoption of database technology in the system, resulting in numerous commercialized and practical CAD systems. Poorang et al. investigated the Web Design Expert module, which provides a complete solution for mold makers and component manufacturers from inquiry to product delivery. Users can complete the whole set of mold designs, including sub-die, standard mold frame, design assembly of standard and non-standard parts, electrode design, etc., and output 2D engineering drawings and NC numerical control machining codes in a unified system environment [5]. Giulia et al. [6] developed a manufacturing-oriented CAD design system, and one of the main product modules is the mold assembly design expert system for mold manufacturing, which can automatically create mold structures and core extraction mechanisms for complex network molds. Obiora et al. [7] introduced a CAD information integration system dedicated to plastic mold design and manufacturing, which integrates all the functions required for plastic product development from product shape design, mold design to mold production, focusing on the association of 3D design and 2D views, reflecting the characteristics of humanization and integration. Due to the rapid improvement of computer performance, polygonal mesh models have been increasingly used in geometric design and computer graphics processing. Xiao et al. [8] proposed an algorithm to solve the distance calculation between point sets of planar line segments by representing the planar lines in CAD diagrams and calculating the chemical network distance between two planar polygons. Jun et al. [9] proposed an approximate network distance calculation algorithm based on the enclosing hierarchical box, using the enclosing hierarchical box structure to continuously filter out the triangular surface pieces that can generate the network distance, which effectively improves the efficiency of calculating the distance between H-angle lattice models. The method makes full use of the special nature of the grid model by continuously traversing the nodes in the octree and finding the node that temporarily has the maximum temporary zed network distance and then traversing all the children of this node to filter out the children that can contribute to the final network distance, which effectively avoids traversing all the points on the grid model [10]. In this paper, we propose a parametric CAD network information integration model containing geometric modeling data and finite element feature attribute data and focus on the composition of the integrated model, data representation in the integrated model, extraction of finite element model, and linkage with the integrated model. Based on this, an injection mold optimization design system based on the CAD network information integration model is constructed, and the system framework, system component modules, system development platform, and development environment are discussed in detail. In terms of CAD integration, because CAD is not a peer-to-peer system, CAD is single application software that operates on the product being designed. The data and documents generated by the CAD system are managed as objects, and CAD is used as an integral part of the application environment to unify the information and its carriers and to coordinate the product development process. The role of human "coordination" between systems will be greatly weakened, and the operational efficiency of each system will be greatly improved.

3 RESEARCH ON OPTIMIZATION OF CAD INFORMATION INTEGRATION SYSTEM BASED ON COMPUTER NETWORK DESIGN

3.1 Computer Network Integration Model Design

For a particular network, let the packet delay be T, which represents the time it takes for the packet to travel from the source node through the network to the destination node. T (h) represents the delay of the packet's header micro slice through the network, and its value is equal to the per-hop router delay (including the delay of the link) multiplied by the number of hops in the router. Since the packet is split into multiple micro slices and serialized for transmission, T (s) represents the serialization time of the packet. The bandwidth, delay time, and power consumption of the link are extracted as parameters of the model, which can concisely and efficiently analyze the link at a high level of abstraction. The delay model of the link is shown in Equation (1), where G represents the number of hops of packets passing through the router, t_a represents the delay of data passing through the router, D represents the size of the packet, and bw is the bandwidth of the channel.

$$T(l) = T(h) + T(s) = Gt_a + D / bw \tag{1}$$

When a packet enters an input port, it is first cached in the cache corresponding to the input port. When the packet reaches the head of the cache in the cache, the routing module starts to calculate the output port of the packet, and then the packet is sent to the row bus corresponding to the input port, and then the packet is temporarily stored in the row cache of the 8x8 crossover switch at the intersection of the row where the input port is located and the column where the output port is located. After that, the cross-switch then transfers the packets from the input row of the cross-switch to the column channel corresponding to the output port and then stores the data in the column cache of the output port (data coming from different cross-switches are stored in different column cache rows). Finally, the multiplexer of the output port arbitrates the column cache, and the winning column cache gets the right to use the output port, and the data in the cache is sent out of the output port to reach the next-hop router.

Figure 1 shows the organization of the CAD integrated model, which consists of geometric data and finite element feature attribute data. The geometric data covers all data information related to geometric modeling such as constituent products, casting systems, cooling systems, injection molds, etc., which are stored in the CAD system's geometric modeling database.

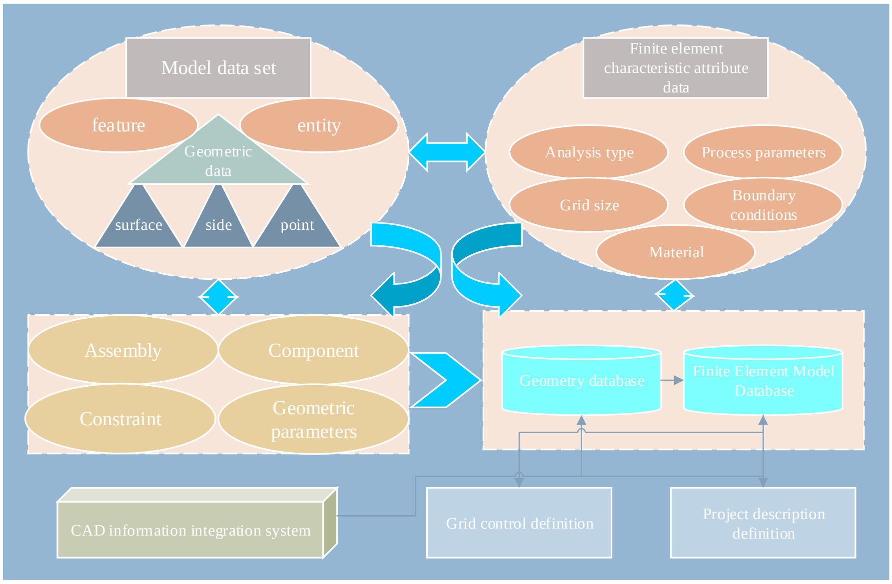

Figure 1: The organizational structure of the CAD integration model.

The main idea of the state enumeration method to solve the network reliability is to calculate the network reliability by enumerating all the mutually exclusive events S_i, i=1, 2, 3 ......K for which the network can operate normally under the specified conditions. The network reliability R(x) is shown in Equation (2).

$$R(x)=\sum_{i=1}^{k}P(S_i)+\int P(x) \quad (2)$$

Given the range of cost values coded and reset according to the order of the high and low individual cost values, this work is chosen to place the most desirable limits on the deviations that may occur in the course of the algorithm, and this fitness function can be constructed as shown in Equation (3), where x is the position of the individual in the cost order.

$$P(x)=\frac{x-1}{\max(R(x))-\min(R(x))} \quad (3)$$

There are multiple paths between the source and destination nodes in the network topology, so the three routing algorithms mentioned above can be chosen. The shortest path between the source node to the destination node is routed by sending the packet upwards to the nearest common ancestor router first and then forwarding the data down to the destination node. The source node 1 and the destination node 2 are shown in Equation (4).

$$\begin{cases} Node(1) = \sum_{i=1}^{n} P(i) * P(i-1) \\ Node(2) = \sum_{j=1}^{n} P(j) * P(j-1) \end{cases} \tag{4}$$

3.2 CAD Information Integration System Optimization Study

Figure 2 shows the framework of the CAD information integration system-based design optimization system. The system consists of five functional main modules, which are CAD integrated modeling, injection molding process parameter setting, finite element analysis calculation, analysis result evaluation, and design optimization. It also includes a knowledge base for process parameter reasoning and three databases, which are: integrated model database, standard mold frame, and standard parts database, and evaluation index set database. The five functional master modules of the system play different roles in each stage of network design optimization and unify the use of the integrated model to complete data sharing and communication.

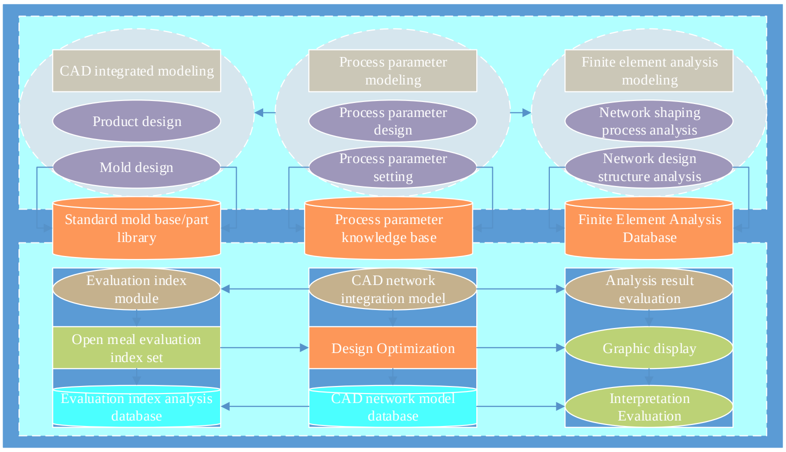

Figure 2: The framework of CAD information integration system to optimize the design system.

The design optimization module is used to specify optimization objectives, design variables, and constraints in case the initial design solution is not reasonable, and the system automatically performs optimization calculations and outputs optimization results. To avoid blindness in design variable designation, the system filters the main control parameters of the model and provides a dedicated setting interface, while the optimization objectives and design variables are selected and set in the open evaluation index set database provided by the system.

By analyzing CAD graphic data and product structure data in detail, the structural relationship between product data is customized in a tight integration mode to be unified, and whenever the CAD mechanism changes, another automatically changes with it, always keeping the assembly relationship of the CAD model and product structure tree synchronized and consistent. The CAD system tight integration model is the best integration model for tight integration, which is generally only available from software vendors. During the integrated design process, the system manager needs to master the software provided by the supplier, define the properties of the CAD file, and set up the user's working environment. Users need to master the integration commands and have the system automatically keep the assembly tree and product structure tree of the CAD software consistent.

The structure and properties of the product can be managed through the integrated database. In the CAD information integration system, the extracted structure information will appear in the form of a structure tree. A product structure tree is a set of interrelated parts assembled according to a specific assembly relationship to form a part, and a series of parts and components assembled organically to form a product. The product is decomposed into parts, and the parts are further decomposed into sub-parts and components, up to the parts, resulting in a hierarchical tree structure called the product structure tree. The CAD information integration system has rich product structure and configuration management functions, providing flexible and convenient product structure editing functions, which are suitable for different manufacturing modes, such as multi-species and small-batch, and complete machines. It can adapt to various configuration modes through variable configuration, validity configuration, version configuration, etc., and can quickly generate and output technical data forms that meet various user requirements.

4 ANALYSIS OF RESULTS

4.1 Network Integration Model Analysis

To test the convergence speed and fitness evolution of the network integration model, two-parameter fitting experiments with search dimensions of 10 and 20 were conducted to record the fitness evolution, as shown in Figure 3.

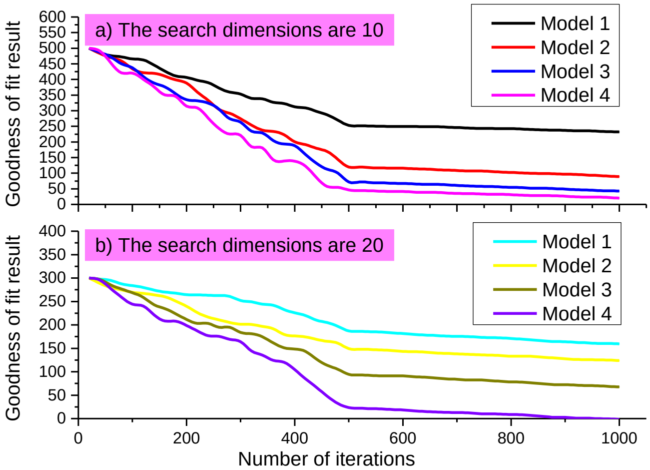

Figure 3: Model fit results.

The evolution of the fitness curve of each model in Figure 3 shows that model 1 has a fast convergence speed at the early stage of iteration, but the convergence speed starts to slow down gradually at the later stage of iteration, and the phenomenon of premature convergence appears. The convergence speed of model 2 is changed by the time-varying acceleration factor, and the convergence speed in the early stage of optimization is slow, but the global searchability in the late stage of optimization is stronger than that of model 1. Models 3 and 4 combine the advantages of models 1 and 2, and the convergence speed in the early stage of optimization is faster, and the global search ability is further improved. Comparing the experimental results, the fitting accuracy of the above four network integration models is 1< Model 2< Model 3< Model 4, where Model 4 is the model constructed in this paper, which proves that the fitting accuracy of this model is the highest.

To observe the variation of the fitness of each model in different search dimensions, the average fitness value obtained by testing the function for 100 experiments with a fixed number of 1000 iterations is shown in Figure 4. From Figure 4, it can be seen that the fitness values obtained for model 4 are significantly higher than the other three models in the same search dimension. With the same parameters, better fitness values can be obtained by increasing the search dimension of the particle swarm. When the search dimension of particles is larger, the fitting error is smaller. From the user's point of view, too many high-level parameters will make the reuse of the sample sketch after exchange not easy. Therefore, it is very important to obtain the sample sketch with a minimum number of high-level parameters to satisfy the interoperability error. When model 4 is used to fit the parameters when the number of interpolation points is 20, the fitness value is 1.85036, the maximum error value is 0.0028, and the average error value is 4.6259*10* (the number of discrete geometric data point set P is 4000). Therefore, when the number of high-level parameters is 20, the interoperability geometric error is in the acceptable range.

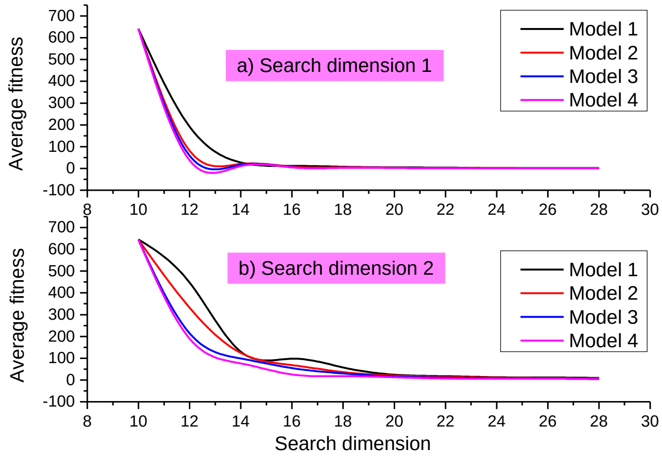

Figure 4: Comparison of the average adaptation values of the four models.

4.2 Analysis of CAD Information Integration System

To analyze and verify the performance of the CAD information integration system, the proposed method is applied to the similarity comparison between point cloud models and CAD models and is experimentally compared with the NAIVEHDD algorithm and EARLY BREAK method. In this experiment, three pairs of point cloud models and three pairs of CAD models are selected, where the network distance T calculation steps between CAD models are as follows: (1) convert models M and model N into STL models; (2) sample the STL models to obtain point sets A and B; (3) calculate the network distance by the equation model. The time consumed by the NAIVEHDD algorithm, EARLY BREAK method, and the algorithm proposed in this paper to calculate the network distance is shown in Figure 5. The experimental comparison shows that the time consumed by the method proposed in this paper in calculating the network distance is much lower than that of the NAIVEHDD algorithm, and at the same time, it surpasses the EARLY BREAK method to a certain extent. This experiment once again confirms the efficiency of the proposed integration algorithm. The results of the optimization analysis are shown in Figure 6.

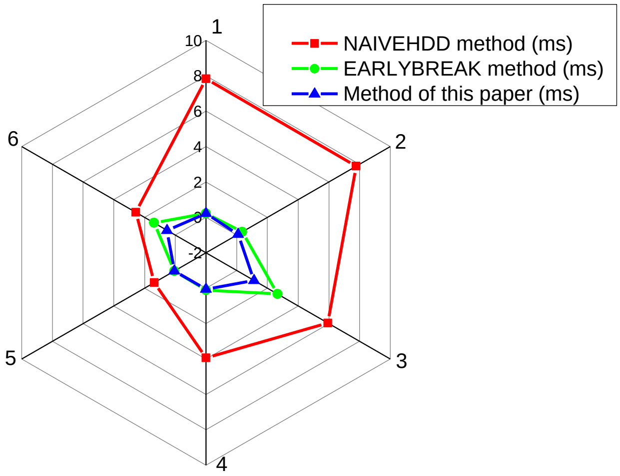

Figure 5: Comparison results of different examples.

The analysis shows that, on the one hand, as the gate moves from the middle of the product to the right end of the product (X direction), the mean square difference of the filling time of each flow path gradually becomes smaller and the balance of the filling increases. The main reason is that the thickness of area 1 and area 2 of the product is thinner than that of area 3, and the melt has the least resistance to flow in area 3. Moving the gate away from area 3 increases the flow of the melt to area 3 while shortening the flow of the melt to area 1 and area 2, which improves the flow balance and reduces the injection pressure and shear stress. On the other hand, as the gate moves from the middle of the product to the lower end of the product (Y negative direction), the symmetry of zone 3 is broken and the flow difference between zone 1 and zone 2 increases, resulting in poor flow balance and increased injection pressure and shear stress.

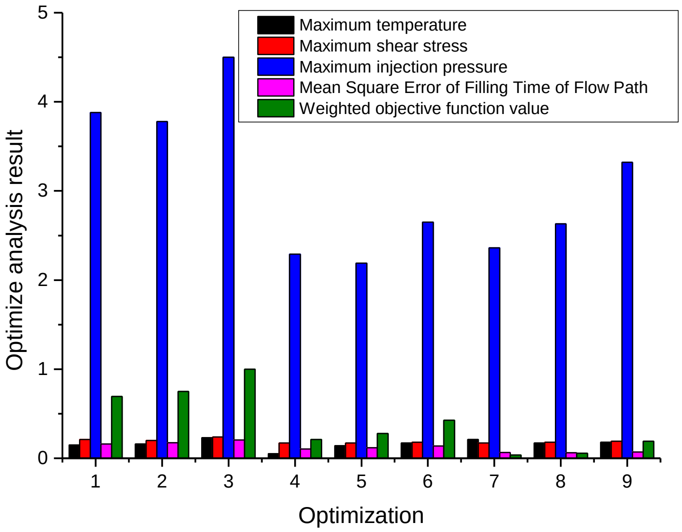

Figure 6. Results of optimization analysis.

From the optimization analysis result data shown in Figure 7, it can be seen more precisely that when B_H is 21.64mm, the maximum deformation of the cavity is 0.04024mm, which exceeds the allowable deformation, and when B_H is 27.27mm, the maximum deformation of the cavity is 0.03904mm, which is within the allowable range. Therefore, 27.27mm is the theoretical optimal wall thickness calculated, but considering the optimization analysis results and mold processing and other factors, the wall thickness of the base plate of the moving mold can be 30mm in the actual design.

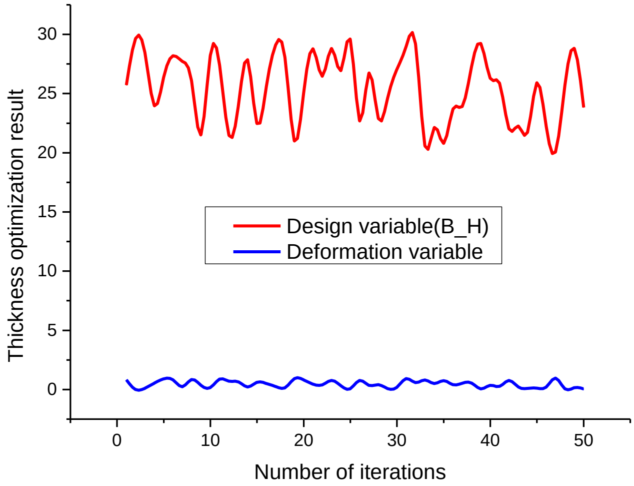

Figure 7: Results of thickness optimization analysis.

With the continuous development of high-performance computing technology, the continuous improvement of system performance and network scale, and the continuous update of related network topologies, routing algorithms, and high-end router technologies, the complexity of high-performance computer design is also constantly rising. Many network modules are involved in the design of high-performance computers. When these complex network components are intertwined and coupled, it is difficult to intuitively analyze the improvement and optimization of the functional structure of some modules in the network to enhance the network performance. Therefore, performing system-level performance simulation in the early stage of high-performance computer design plays a vital role in the design of high-performance computers. This paper proposes a network integration model design optimization method based on structural analysis, rationally simplifies the structure of the network integration model, and establishes a corresponding force analysis model. Combining the melt pressure field data obtained from the CAD analysis of the product and the mold grid unit information, these data are reasonably matched to complete the application of the mold cavity load, and the deformation analysis of the mold is realized in the CAD information integration system, and based on the analysis As a result, the wall thickness of the network mold was optimized.

5 CONCLUSION

The organic integration of CAD technology to improve the automation and intelligence of the product development process is the main development trend of future engineering design. In this paper, the problems in the network design process are addressed, CAD system integration and optimization design methods are thoroughly studied, and a prototype system of network optimization design based on CAD information integration is developed. In the integrated system, the optimization of the CAD information integration system is realized by using the method of refining the slice model with contours, and the difficult problem that the CAD system cannot express the color gradient of the finite element mesh model is solved. An open evaluation index set for design optimization is established, and the automatic evaluation of network design solutions is realized through the calculation of optimized index values in the index set and the mathematical determination of constraint indexes, based on which the design optimization process and design optimization methods based on computer network design are proposed. The CAD integration model can be used to realize the integration of multidisciplinary analysis programs on the optimization design system to achieve the perfect combination of plastic products in appearance, performance, formability, reliability, and other aspects, but different analysis programs target different optimization objectives, and how to realize the information fusion of multidisciplinary analysis is the focus of the next research work. The CAD integration method proposed in this paper has good portability and can be implemented on other CAD software with a parametric modeling function and a professional secondary development interface.

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