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CDA-based Parallel ADI Computing Algorithm of Three-Dimensional Structure Design of Contemporary Ceramic Sculpture

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Abstract. With the development of the times, the progress of society, the integration and innovation of modern science and technology and traditional culture and art, the modeling and decoration design of ceramic sculpture products have developed to the present day, and there are progress and development in different levels in both the production technology and the expression techniques. Ceramic sculpture design can not only be expressed on drawings, but also be simulated by computer modeling and decoration, and the scheme can be modified at any time, so that the preset effect of ceramic sculpture products in the future and the unique glaze color effect can be virtually preset. Aiming at the design of large-scale management information, this paper proposes an object-oriented analysis tool, strategy and model of the extended information system, and applies iVsualModelo: 2.0 based on "Unified Modeling Language" UML as the design tool of ceramic sculpture management information system, realizing the high integration of object-oriented analysis, object-oriented design and object-oriented programming. This paper analyzes and studies the application of computer aided design technology in all aspects of product design, and further proposes the application field of virtual reality technology in the research process of ceramic sculpture products. The overall artistic image of ceramic sculpture products is displayed through the cooperation of other animation functions and later software.

Keywords: Deep Learning; Computer Aided Technology; Ceramic Sculpture; Three-Dimensional Structure Design.
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1 INTRODUCTION

Nowadays, computer technology has become an important social production technology, and digital technology with computers as tools is widely used in daily life and production, involving more and more fields [1]. As a perceptual expression, the art field is inevitably deeply influenced by computer digital technology in its creation form and expression way. Digital technology provides unlimited possibilities for artistic creation, and the computer artists born from this have become new things and important groups of artistic creation in the digital age [2]. In many fields of social development, science and art work together in our lives, or the boundary between art and science is increasingly blurred, and they work together in all aspects of our lives. In the interaction and combination of art and science, now computer-aided technology not only plays an important role in the fields of plane, environmental art, film and television, animation, etc., but also has penetrated into the field of landscape sculpture design, and profoundly influenced such complex subject arts as landscape sculpture design [3].

Ceramic industry is an old and young industry. Computer aided design technology has injected new vitality into the series design process of household ceramic products. However, due to the special properties of ceramic materials -- shrinkage, deformability and strong ductility, the design and manufacture of ceramic products have a unique process, resulting in increased complexity of computer simulation [4]. The 3D printing technology of ceramic materials is an innovation of traditional ceramic forming technology, which makes modern ceramic products have new modeling forms and features. This paper makes use of the technicality and uniqueness of 3D printing of ceramic materials, and according to the application value and development trend of 3D printing of ceramics in product design, conducts research on the design of interesting, novel and practical ceramic industrial products [5].

In 3DSMAX, through its powerful animation function, the process of product modeling and decoration can be recorded in the form of key frames, so as to observe the dynamic change process of morphological composition and surface texture. The application process of 3DSMAX modeling animation and material animation in ceramic product modeling and decoration design is studied by key frame animation. The modeling and material animation functions of 3DSMAX are applied to ceramic product modeling and decoration design. The modeling process of ceramic product modeling and decoration process of ceramic products are displayed by various methods of modeling, and various types of materials are displayed by animation. The specific design application shows the fusion innovation of technology and art. Inheritance and development are as important as ceramic design, but at present, computer design, a new design medium, can be applied to ceramic design to open up a new field of ceramic design. The revolutionary achievements brought by the combination of art and science and technology, as well as new ideas and inspirations for traditional ceramic product design, thus promoting the new development of ceramic design theory and practice.

According to the characteristics of ceramic enterprises, a set of CAD/CAMC/AE solution based on computer network for ceramic enterprises is proposed, and several key problems are discussed. Its innovation lies in: (1) Through the study and practical operation of 3D software, we can understand the advantages and disadvantages of different 3D software, actually participate in sculpture art production, deeply understand the production methods and processes of modern sculpture production technology, sort out the knowledge points related to 3D modeling assisted sculpture creation, sort out and summarize, and find out the deficiencies in the learning process. (2) Contact the production process in the sculpture project work to avoid talking on paper. At the same time, we have a deep understanding of the production process of each link and the work of digital technology in each link of sculpture art. The feasibility of digital technology in sculpture art is obtained. Through the comparative analysis of computer-aided sculpture design and traditional landscape sculpture, the advantages of computer-aided sculpture are obtained. It also demonstrates that computer aided sculpture is the product of the development of the times.

2 RELATED WORK

Computer aided sculpture design puts forward more extensive and higher requirements for the cultivation of sculptors' quality and ability. It requires sculptors to have a wider range of knowledge and basic skills, and the ability to drive and refute other means other than traditional sculpture creation, as well as the ability to skillfully use computer software. In today's modern and information-based society, it is more necessary to skillfully use computer aided operation, and the cultivation of this comprehensive ability is also more urgent.

In view of the shortcomings of domestic and foreign computer aided innovative design software in problem analysis tools, innovative solution strategies and knowledge base, Li and Li [6] proposed a computer aided innovative design platform model based on the characteristics of product innovative design and technical innovation implementation methods. As a computer aided tool, the platform can help designers to carry out innovative design, and open the designer's thinking space in the process of problem analysis, strategic solution, knowledge data support and program management evaluation. Qin et al. [7] introduced several common chest X-ray datasets, and briefly introduced general image preprocessing programs, such as contrast enhancement and segmentation. CAD systems for detecting specific diseases (pulmonary nodules, tuberculosis and interstitial lung diseases) and multiple diseases are described. The basic principle of the algorithm, the data used in the research, the evaluation measures and the results are mainly introduced. Sun et al. [8] used calculation tools to analyze the design of ceramic products, and used three-dimensional methods to deal with the design. On this basis, the application of 3D printing technology in ceramic field is discussed. Secondly, through personal design and experiments, the principle of using machines in the 3D printing process of ceramics and the characteristics of 3D printing ceramic modeling are summarized. Finally, according to the characteristics of ceramic 3D printing technology, combined with the principles of aesthetics and modeling design, ceramic 3D printing technology is applied to the design and production of ceramic modeling. I hope it can provide reference for expanding the space of ceramic modeling design, and provide more possibilities for the future development of ceramic modeling design. Computer assisted surgery has been widely used in the treatment of hemifacial microsome, and has matured in recent decades. These technologies include computer aided design, virtual surgery planning, modeling surgery, rapid prototyping technology, intraoperative navigation, etc. Sun et al. [9] aims to summarize the application status of CAD/CAM technology in hemifacial microsome therapy in recent years, as well as the views and discussions on some topics, and finally introduces our team's methods. Avoid potential bone rotation caused by mismatch between traditional titanium plate and bone surface, which will make bone fixation accurately consistent with preoperative virtual plan, and reduce bone segment movement caused by unexpected stress of titanium plate. Due to the ongoing bone remodeling, muscle stretching, occlusal disorder and other factors, it is difficult to accurately reset the physiological position of the mandibular condyle and mandibular ramus in clinical practice; This makes it difficult to reconstruct the mandible to obtain a good shape and a good condylar position. Ren [10] aims to study the standardized method of mandibular reconstruction in old mandibular defect cases through computer aided design enhanced three-dimensional (3D) printing surgical template. We collected CT data before operation to calculate the physiological position of mandibular condyle and ramus in sagittal, axial and coronal planes. Then, surgical simulation and 3D printing template preparation are carried out to help implement actual surgery.

3 METHODOLOGY

3.1 The Concept and Development of Computer Aided Ceramic Sculpture Design

Modeling activities observe and know the physical structure characteristics of the object from the macroscopic and microscopic angles through the physical structures of the objective world, such as natural, geometric and organic bodies. Through feeling, analysis and cognition, the concepts and forms of all kinds of substances that contribute to the physical modeling are processed and changed by different methods according to the needs, making it a new ceramic modeling. The morphological components of ceramic products are shown in Table 1.

Structural elements	*The combination, connection mode and*

	connection method among the elements that constitute a specific thing are the pursuit of human beings for "good" and "truth" of products in accordance with the purpose.
Formal elements	It is an important carrier of product function and emotional connotation. The rational content is based on the objective rational law of things to people; The connotation of emotion is based on the cognition of the subjective psychology of the aesthetic subject.
Functional elements	The foundation of practical value, the premise of creating symbolic value, and the main elements of the aesthetic object of technical products. It mainly includes technical function, character matching function (human factor) and aesthetic function.
Artistic elements	It has special value in improving people's aesthetic ability and promoting the direction of social life. It has certain image, infection, sociality and novelty.
Technical elements	As the technical function of things, the matching function with people, the economic function of society, and the environmental function, technological products have the characteristics of utilitarianism, practicality, and modernity.

Table 1: Basic forms and connotations of ceramic product form elements.

The construction of design semantics is to make the meaning conveyed by the design language have a certain degree of commonality and accuracy. To understand the design language, we must analyze its nature and the characteristics of the interrelationships and differences between the levels from the different levels that constitute the design language. Like the basic elements of linguistic structure, it has three levels: grammar, semantics and pragmatics. Therefore, people may analyze other things and forms according to the verb meaning of the word "design". In the th century, some people also interpreted works of art as the sum of works "design" and turned their attention to the solid process of works. The main task of design is often expressed as a construction of form, and the extension of design meaning takes design as a language bridge to communicate the understanding between the creator and the user. Sculpture space is not only concentrated in sculpture and sculpture's internal space "penetration", but also its volume sculpture, body mass or volume, and sculpture itself will constitute space. As shown in Figure 1, the Greek sculpture Laocoon.

It is reflected in the space between the characters and the main body, the space between the main body and the snake, the relationship between several characters and the rhythm between the performance of the movement state. In other words, the sculptors dig out or remove the redundant space, and use snakes to interpenetrate and maintain several individual individuals.

Therefore, three-dimensional sculpture, depth awareness, aesthetics, etc. are closely related to space.

Figure 1: Laocoon.

3.2 Application of 3DMAX Modeling Animation in Ceramic Product Modeling Design

The essence of new product development is this process, which involves the conversion, processing and feedback of all kinds of information, data and corresponding information data. That is to say, each local working segment that completes a specific function has good encapsulation, and the process of product parallel development is a process of optimizing product development through local working segments and asymptotic iteration. As shown in Figure 2.

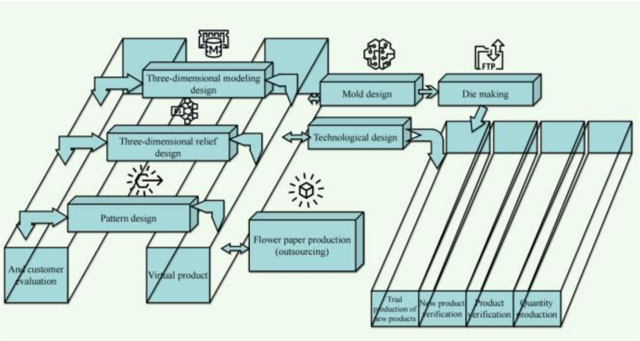

Figure 2: Concurrent Design and Manufacturing Process of Ceramic Products.

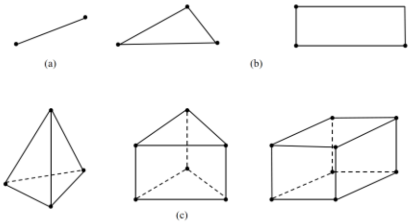

Figure 3: The basic element (a) in the finite element is one-dimensional; (b) 2D; (c) 3D.

Figure 3 shows the different dimensions of the basic elements in the finite element. (a) It is one-dimensional; (b) It is two-dimensional; (c) Three dimensional. The interpolation function in finite element analysis generally selects first-order (linear), second-order (quadratic) or higher-order polynomial. The higher the order, the more accurate the calculation results and the more complex the calculation formula. Generally, the first-order polynomial is selected as the interpolation function. After the interpolation function is selected, we can express the function expression of each cell. Taking the cell as an example, we can get the following form:

$$\tilde{\Phi}^e = \sum_{j=1}^{n} N_j^e \tilde{\Phi}_j^e = \{N^e\}^T \{\Phi^e\}^T \{N^e\} \tag{1}$$

Where n is the number of nodes in the unit, and for the first-order tetrahedral unit, the value is 6; $\tilde{\Phi}_j^e$ The value of the node in unit e ; Is an interpolation function, also known as a basis function or an expansion function.

Write in the same matrix form:

$$\left\{\frac{\partial F^e}{\partial \Phi^e}\right\} = [K^e]\left\{\Phi^e\right\} - \left\{b^e\right\} \tag{2}$$

Among them:

$$\left\{\frac{\partial F^e}{\partial \Phi^e}\right\} = \left[\frac{\partial F^e}{\partial \Phi_1^e}, \frac{\partial F^e}{\partial \Phi_2^e}, \ldots, \frac{\partial F^e}{\partial \Phi_n^e}\right] \tag{3}$$

Generally speaking, through the relationship between local and global node codes, the matrix $\left[K^e\right]$ is expanded into a matrix by adding zeros, and it is also expanded in the same way.

Through the previous steps, we can get the equations:

$$\left[K\right]\left\{\Phi\right\} = \left\{b\right\} \tag{4}$$

After obtaining Φ , the required parameters can be obtained, and the results can be displayed in the form of charts and curves. This step belongs to the post-processing process and is independent of other steps.

3.3 Application of 3D Semantics of 3DS in Ceramic Design

Ceramic design has a long history, from the initial simple manual manufacturing to the present industrial design and production. Such a long historical process has created the magnificent and splendid ceramic art. However, under the influence of modern information technology, computer art, as a new design language, has penetrated into the ceramic design field, impacting the original traditional production mode. Designers use computer as a new medium and new design language in the design field, which has a direct impact on the development of ceramic design. The 3D modeling language of MAX itself is obvious. Applying the modeling rules and modeling rules in product design concepts to the new expression, giving full play to the dominant role of the state, and embodying the ceramic design works to be displayed, can well guide designers to innovate their thinking on ceramic design. Thus, we can get:

$$\begin{cases} S_v(X) = \int_{y_1}^{y_2} IMG(x,y)dy = \sum_{y=y_1}^{y_2} IMG(x,y) \\ S_h(y) = \int_{x_1}^{x_2} IMG(x,y)dy = \sum_{x=x_1}^{x_2} IMG(x,y) \end{cases} \quad (5)$$

Corresponding to the integral projection functions are the average integral projection functions $M_y(x)$ and $M_h(y)$, which are defined as follows:

$$\begin{cases} M_v(x) = \frac{1}{y_2-y_1} \int_{y_1}^{y_2} IMG(x,y)dy = \frac{1}{y_2-y_1} \sum_{y=y_1}^{y_2} IMG(x,y) \\ M_h(x) = \frac{1}{x_2-x_1} \int_{x_1}^{x_2} IMG(x,y)dy = \frac{1}{x_2-x_1} \sum_{x=x_1}^{x_2} IMG(x,y) \end{cases} \quad (6)$$

Moreover, it is easy to know that the maximum number of parallel subproblems at this time is $ny \times nz$, where ny indicates the number of discrete points in the direction of y, indicating the number of discrete points in the direction.

$$-r_x T_{i-1,j,k}^{n+(1/3)} + 2(1+r_x) T_{i,j,k}^{n+(1/3)} - rx T_{i+1,j,k}^{n+(1/3)} = r_x T_{i+1,J,K}^{n+(1/3)} \quad (7)$$

$$2r_y T_{i-1,j,k}^{n+(1/3)} + 2r_z T_{i,j,K-1}^{n} \quad (8)$$

If the above equation group is replaced by matrix, it is:

$$M \frac{T^{n+1/3}}{\Delta t} + K_x \frac{T^{n+1/3} + T^n}{2} = P_e - (K_y + K_z) T^n \quad (9)$$

Parts is the number of subtasks, and Block defines the calculation area of subtasks. The following figure describes the process of load balancing by taking only the heat conduction in the y direction as an example. A in the figure is the ideal structure of blocking, while B needs to assemble the computing nodes in two lines together.

Compared with CPU, GPU, which has been focused by academia and industry in recent years, has stronger parallel capability, lower cost and lower power consumption. As a powerful general-purpose processor, the CPU is designed to focus on complex branch prediction, cache systems and various logic controls, while the GPU uses most transistors on the chip as pure computing units. This architecture determines that the GPU has strong floating point computing capabilities. As shown in Table 2. The performance parameters of a desktop quad core CPU and a desktop consumer video card are compared.

Chip name	*Process size*	*Chip size*	*Transistor*	*Clock frequency*	*Number of threads*
IntelCore2QX 9650	45	625	851	3.25	4.26
NVidiaGTX280	66	658	1452	1.32	998

Table 2: CPU and GPU separate parameter table.

Generally speaking, the number of transistors on GPU in the same period is more than that of CPU. These transistors serve the computing core on GPU, but this core structure is relatively simple. It can be understood that the advantage of GPU lies in the large number of cores.

Distance transformation is a kind of transformation for binary images. The distance transformation of a point can be defined as the shortest distance from the point to the boundary point. We can describe it in mathematical language. For the binary image $A_{m\times n}=\{A(i,j)|A(i,j)\in\{0,1\},1\leq j\leq n\}$, it contains point sets P (background point) and Q (front scenic spot):

$$\begin{cases} P=\{A\{i,j\}|A\{i,j\}\in\{0\},1\leq i\leq m,1\leq j\leq n\} \\ n=\{A\{i,j\}|A\{i,j\}\in\{1\},1\leq i\leq m,1\leq j\leq n\} \end{cases} \tag{10}$$

In addition, there is a distance measure function $D(q,p),\{p\in P,q\in Q\}$, so a point in the background point set P corresponds to the distance transformation

$$DT(p)=\min\{D(p,q,|q\in Q\} \tag{11}$$

For a point $q(q\in Q)$ in the front scenic spot set Q, the corresponding distance transformation

$$DT(q)=\min\{D(q,q,|\in Q=0\} \tag{12}$$

In this method, we make comprehensive use of their advantages, combine them by weighting method, and finally get the three-dimensional text data Height out,

$$\begin{aligned} &Height\_out=Fun(Height\_1,Height\_2) \\ &=k_1\times Height\_1+K_2\times Height\_1 \end{aligned} \tag{13}$$

Parameters of unknown quantities in the above formula are:

$$-a_{i-1}k_1,b=b_i-c_{i-1}k_1-a_{i+1}k_2 \tag{14}$$

$$k_1=\frac{a_i}{b_{i-1}},k_2=\frac{c_i}{b_{i+1}} \tag{15}$$

After the above steps are executed, there are only two equations left, so that two unknowns can be solved, and then the second process of CR algorithm: Back-substitution, in which the remaining odd-numbered unknowns can be solved by x_{i-1} and x_{i+1}. The specific formula is:

$$x_i=\frac{d_i-a_ix_{i-1}-c_ix_{i+1}}{b_i} \tag{16}$$

4 RESULT ANALYSIS AND DISCUSSION

This section uses the ADI parallel algorithm mentioned above to simulate a specific example. This example is an integrated packaging structure with TSV array. The top layer is a heat sink, the bottom layer is a packaging substrate, and the middle layer is alternately composed of a micro solder ball layer, a silicon through-hole array insertion layer, and a chip. We use the equivalent thermal modeling method to deal with the solder ball layer and silicon via array insertion layer. After the thermal simulation of CUDA-ADI algorithm, we observed the temperature rise distribution on the upper surface of silicon via. Figure 4 shows the temperature distribution on the observation surface of CUDA-ADI and COMSOL respectively in 3s. It can be seen that their heat distribution is the same. In order to further verify the correctness of CUDA-ADI algorithm, we also draw a temperature rise distribution diagram of a sampling point, which is also compared with the temperature rise distribution of the same sampling point of COMSOL. The results are shown in Figure 4.

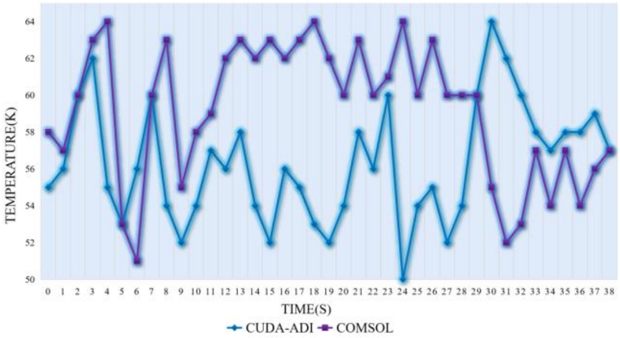

Figure 4: Cross-sectional view of the model.

It can be seen from the figure that the simulation results of the two are basically consistent. From the analysis of the results of Figure 4, it can be seen that the final temperature has not dropped to room temperature because the chips 1 and 2 have been working. As shown in Figure 5.

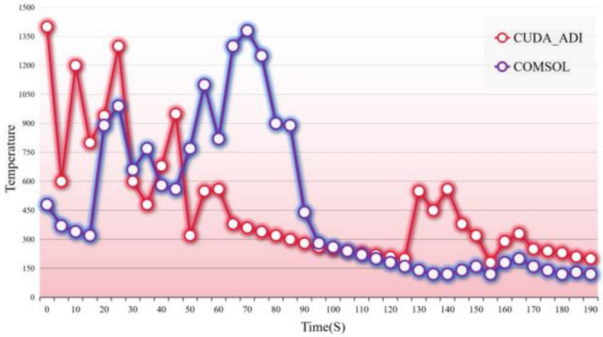

Figure 5: Comparison of simulation results between 5CUDA-ADI and COMSOL.

To investigate the efficiency of CUDA-ADI algorithm, Table 3 lists the running time of GPU parallel CR and single core CPU with node changes in solving ADI tridiagonal equations. It can be seen from the table that the parallel CR algorithm based on CUDA architecture is about 20 times faster than the traditional single core CPU implementation.

Grid size	*Number of nodes*	*Serial calculation time (seconds)*	*Parallel computing time (seconds)*	*Acceleration ratio*
50*50*90	79692	3.23	0.23	20.332
60*60*90	123856	0.35	0.26	16.235
100*100*90	320665	23.145	0.82	22.6922
160*160*90	865201	83.56	2.63	23.26

160*160*140	1652654	682.66	9.15	26.24

Table 3: Simulation Diagram of 3D Packaging Structure.

After HFSS simulates the electrical information of the model, the software extracts the grid information and power density of HFSS simulation results, but HFSS only provides users with tetrahedral grid information and partial surface information of the structure. In thermal simulation, it is necessary to add boundary conditions to the structure through the grid information of the structure surface, and in drawing, it is also necessary to draw the thermal distribution of the structure by the surface grid.

In order to solve the above problems, the software has developed a set of algorithms, which can quickly calculate the external surface mesh through the existing tetrahedral mesh without the user having to export the surface mesh information separately. As shown in Figure 6 and Figure 7.

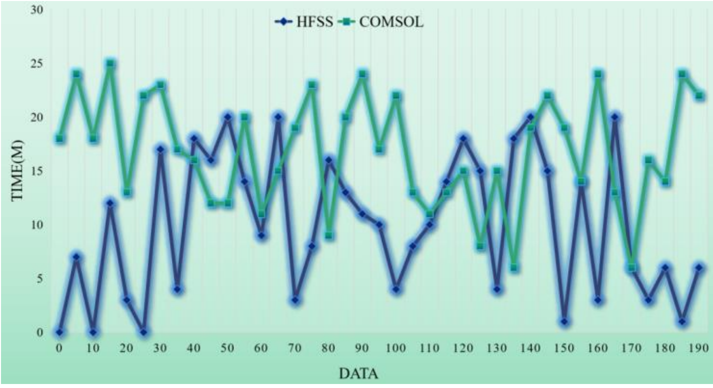

Figure 6: Structure diagram of HFSS via microstrip line.

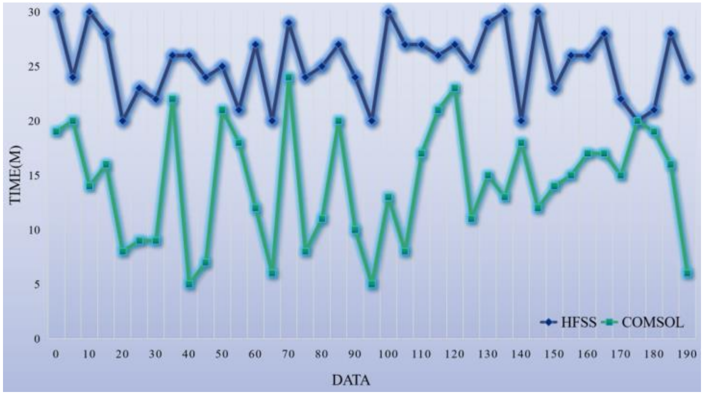

Figure 7: Setting material parameters and boundary structure diagram.

Then HFSS is used to simulate the structure. After the simulation, the grid and loss information of the model are derived. According to the simulation sequence in the previous section, call the preprocessing module to analyze the grid and loss files, and generate new file information for use in the heating simulation program.

5 CONCLUSIONS

Max is a three-dimensional design software based on PC system developed by Autodesk Company. Its most prominent advantages lie in modeling, material and animation. It can produce arbitrary three-dimensional shapes, accurate surface decoration and realistic high-end animation. The application of three-dimensional modeling software in ceramic sculpture in sculpture art is more and more extensive, and the use of three-dimensional modeling software has changed the creative technique of sculpture art. Nowadays, sculpture art creation uses 3D modeling software, which simplifies the process of creative realization, increases the complexity of creativity, and makes artistic modeling diversified. Deformation and abstract processing in 3D modeling software can stimulate sculptors' artistic senses and make sculpture artistic forms diverse. In the research of parallel algorithm for thermal simulation, first of all, based on the theory of ADI algorithm and multi-core CPU computer system, parallel ADI computing programs were written using the operating system thread function library and OpenMP respectively. On this basis, thread pool technology and thread binding technology were introduced to optimize the algorithm, reducing the time consumption caused by thread creation and destruction and switching between threads, The accuracy and efficiency of parallel ADI algorithm based on multi-core CPU system are verified.

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