Discussion on Teaching and Learning Strategy of Industrial Product Design Skill Competition

Yuanyuan Chai[1,*] and Qiang Li[2]

[1]School of Art and Design, Zhengzhou University of Aeronautics, Zhengzhou, Henan 450046, China, Chaiyy@zua.edu.cn
[2]School of Art and Design, Zhengzhou University of Aeronautics, Zhengzhou, Henan 450046, China, levisBJ@163.com

Corresponding author: Yuanyuan Chai, Chaiyy@zua.edu.cn

Abstract. With the continuous development of the current economy, the demand for talents with professional skills is becoming wider and wider. Computer-aided design (industrial product CAD) skill competition is one of the skills competitions in national vocational colleges, which requires high comprehensive ability of students. As an important means to improve product level and added value, industry design has been gradually recognized and adopted by manufacturing enterprises in China, and the combination of information technology and design has greatly improved the efficiency of product development. Through the analysis and research on the application of industrial design in manufacturing enterprises in China and the application of CAD in product development, many conclusions have been drawn, such as the setting of industrial design departments in manufacturing enterprises in China, the cognitive level of industrial design, the important factors in new product development, the use of CAD, the mastery of CAD by designers and the use of 3D CAD in product development. This study provides a good objective basis for the popularization of engineering CAD three-level skills and technology, and for the individual or batch test of learners' operation level. It has important practical significance for the establishment and improvement of CAD skill level test standards and evaluation content system.

Keywords: Industrial Product Design; Skills Competition; Strategic Coaching; CAD.
DOI: https://doi.org/10.14733/cadaps.2023.S8.100-111

1 INTRODUCTION

The history of human civilization is a history of human practice and continuous innovation. With the development of human cognitive ability and the accumulation of knowledge, innovation plays an increasingly significant decisive role in economic prosperity and national prosperity [1]. China's mechanical and electrical products not only have to bear the fierce competition in the domestic market, but also have to face the fierce impact of foreign products. Good quality and low price.

However, the original general CAD software is increasingly out of line with the social inevitable trend of detailed design and production division, and it seems inadequate in the design of special products [2].

Computer Aided Design (CAD) is a kind of computer software that has been widely used in recent years. It is also a multidisciplinary application technology that combines industrial design methods with the latest computer science [3]. Its function is to help engineering designers complete the whole design process of products, such as various calculations, analysis, drawings, etc. required by the product design process, and also to complete the preparation of technical documents, and finally output the drawings that meet the design requirements [4]. The wide application of CAD has greatly improved the design efficiency of industrial products, greatly shortened the cycle from drawing design to the commercialization of finished products, and significantly promoted the development of industrial products [5]. The development of CAD technology involves many contents, such as: 2D and 3D design of engineering and products, assembly simulation and motion simulation, static and dynamic simulation of process, image rendering, data programming, accurate management of engineering and product database, design and generation of different files, and so on. At the same time, there is a big gap between the research work of computer aided technology in China and the developed countries in Europe and America. A large number of key technologies of computer aided design are still mastered by those developed countries. However, all kinds of high-end CAD software are available in microcomputer version, which provides an objective basis for the popularization and deepening of CAD software in all walks of life.

It is a good trend for talents to hold vocational skills competitions in China. The content of the vocational skills contest is based on the current economic development's demand orientation and job requirements for talents, and closely follows the social demand for talents. The starting point of school education for students is to closely follow the trend of society's demand for talents, so as to educate the talents who meet the needs of social development enterprises, so as to quickly Kamijozu in the corresponding positions and realize the seamless link with enterprises. Incorporating the guiding ideology of the Industrial Product Skills Competition into the course of Industrial Product Design CAD for computer majors can not only meet the high requirements of students, guide them to learn actively, improve their professional skills, but also explore their potential in the process of learning and cultivate competitive students. The contest designated Inventor as a software to complete the creative design of a small consumer electronic product. This project requires students not only to have skilled software operation skills, but also to have the design ability of product appearance and the assembly ability of product internal structure. Therefore, teachers should not only consider the use and operation of software and product design, but also know how to select students and improve teachers' comprehensive level.

This paper introduces the Inventor tool software and drawing, product design, independent innovation and other aspects, and then briefly analyzes the relationship between the domestic CAD competition and the world CAD competition, which has a certain guiding role for the skill training of the industrial product CAD competition. The rigid body transformation parameters are dynamically adjusted by step factor. The specific process of this method is as follows: firstly, a step factor is added in each iteration of ICP algorithm to realize the overtravel transformation of the original measurement point cloud; Then calculate the matching error after each iteration. If the error decreases, continue to increase the step factor, thus improving the matching efficiency and improving the registration accuracy.

2 RELATED WORK

With the change of part design means from two-dimensional space to three-dimensional, the corresponding tolerance also changes from two-dimensional space to Wang Wei, and its detection means also develops rapidly from two-dimensional space to H dimension. In recent years, the technology of obtaining the H-dimensional data of real objects has been paid attention to and studied for a long time, and has made a good development. The process of obtaining point cloud is the measurement process. It mainly includes two parts: First, on the basis of the existing mechanical products, using innovative theories and methods to improve or perfect their technical performance, economy, reliability and applicability; Second, according to the needs of the society, enterprises and users, under the unknown conditions of working principle and basic structure, we should use mature scientific theories or various innovative design methods to create and design new products and machines to meet the new needs of human beings.

Lee et al. [6] compared the effects of injection molding, milling and rapid prototyping on the accuracy of denture base. Materials and methods. The maxillary edentulous mother mold is made into four circular notches. In the injection molding method, the designed denture base is grinded from wax blocks and manufactured using the SR Ivocap injection system. The conclusion shows that the overall accuracy of milling and RP denture base is higher than that of injection molding. The precision reproducibility of injection molding method is higher than that of milling or RP method. Rawi et al. [7] can easily simulate the final structure and effect of the product realization in the computer, and conduct test and comparison. It greatly saves time and reduces the cycle and cost of product development. Whether it is the concept and rendering performance in the design stage, or the engineering drawing performance in the creation and realization stage, it is inseparable from the participation of technology. The use of this computer-aided software has greatly improved the design and provided wings for creative realization. With the development of computer graphics technology, computer-aided design has penetrated into all stages of product design. The main content of the "industrial product design (CAD)" project competition is product design, and the computer is only an auxiliary tool. Students majoring in numerical control and mechatronics have the ability to design the product shape and assemble the internal structure of the product in terms of professional knowledge. Saleh et al. [8] analyzed the function and selection of 3D rendering software. Through the software for modeling and effect performance, the creativity of product design can be displayed in the way closest to the real object. The 3D software modeling and effect performance is the final aspect of product modeling design. An industrial designer's software that covers all aspects of computer-aided industrial design was first used in the design field. TrzepiecińSki et al. [9] uses NUBRS surface design software, which is good at surface design, to analyze and design industrial products. It can realize various functions such as sketch, modeling, rendering and presentation. The results show that the biggest advantage of the software is that it can produce a realistic rendering effect like a photo without complicated settings. At present, it is widely used in design enterprises and companies. Industrial design is increasingly integrated into integrated design and manufacturing systems. Integration of industrial design and digitalization with the development of information technology, digitalization has become a trend. Industrial design, which is the basis of product manufacturing in the early stage, has also been connected with digitalization, and many new methods and concepts in the form of digitalization have been applied to industrial design. Tsujimoto et al. [10] has designed relevant materials and processes to make the products more humanized and more in line with the physiological and psychological needs of users, and speed up the dissemination of information.

3 METHODOLOGY

3.1 Basic Information of the Industrial Product Design CAD Competition Project

The purpose of constructing computer information network technology in practical teaching is to enable students to apply the basic theoretical knowledge they have learned to practical life. However, according to the actual teaching results at present, teachers basically only pay attention to students' mastery of basic theoretical knowledge, ignoring the training and guidance of students' practical application ability. In the process of vocational education, the ideas of taking projects as carriers, taking work tasks as guides and taking actions as guides advocated in competitions are fully combined. Combining the idea of skill contest with practical education can achieve the goal of promoting teaching through competition, improve students' professional skills and achieve students' life goals. In order to achieve excellent results in the competition, students should pay attention to observe the appearance and function of some light industrial products in their daily life, find out the shortcomings and improvements of these products, and fully mobilize the creativity of the brain to use the designated Inventor software to design their own satisfactory products. However, the design process must conform to the actual logical relationship. However, there are few students who can do this. For example, for mechanical majors, their strong points are drawing recognition and skilled use of AutoCAD software drawing, and strong basic knowledge of machinery and engineering materials, but their weakness is poor rendering ability of products. Among them, the segmentation of characteristic rectangular faces is the most characteristic, as shown in Figure 1.

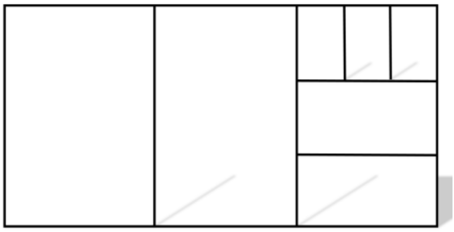

Figure 1: Segmentation of characteristic rectangular surface.

In modeling, people often use the most stable figures (squares, RMS rectangles, etc.) as the basic figures. It is generally believed that these figures can achieve a good number ratio relationship and aesthetic feeling. By applying their evolutionary relationship and dividing them into evolutions (or combinations) according to their functions and artistic requirements, the artistic effect of the combination of dynamic and static shapes and mutual echo and coordination can be obtained, so that the division of the shapes can be carried out according to a certain number ratio law, thus obtaining the beauty of the modeling ratio.

In the modeling of 3D parts, special emphasis should be placed on the use of constraints: coincident constraints, collinear constraints, concentric constraints, parallel constraints, vertical constraints, vertical constraints, tangent, smooth, symmetric, and equal constraints. Many high-end 3D software introduces parametric and variable modeling technology. Parameterization is to assign independent parameters to each independent size of solid components. When the system is running, users only need to type in the relevant parameter values, and the system can automatically generate the required 3D model of components, which is fast and efficient, especially important for serial design. Variable design refers to a method that each independent variable can have a mathematical relationship with some of the variables, so that the calculation and assignment of relevant parameters can be obtained only by giving its relationship formula, so as to quickly generate 3D modeling.

3.2 Framework Model of Generalized Modular Rapid Design System for Mechanical Products

Modular design technology constructs new products by dividing mechanical products into modules and reorganizing them, realizes mass production of customized and personalized products, and enhances the core competitiveness of enterprises. Product generalized modular design tool set is an intelligent, parametric and variable design tool set with modular design as the core and CAD software as the support platform. Rapid design software tool set is a rapid design software which is built on mature CAD software but has its own relative independence. The user's final product realization needs to transmit the product data to the supporting software platform through the pipeline (secondary development interface), so as to generate the final holographic product model including the three-dimensional model. This requires the rapid design and application of specific products through the secondary development of mature CAD software. According to their functions, these rapid design software tool sets can be divided into three layers as shown in Figure 2: the supporting platform of the design tool sets and the rapid design enabling tools for realizing specific methods or tasks.

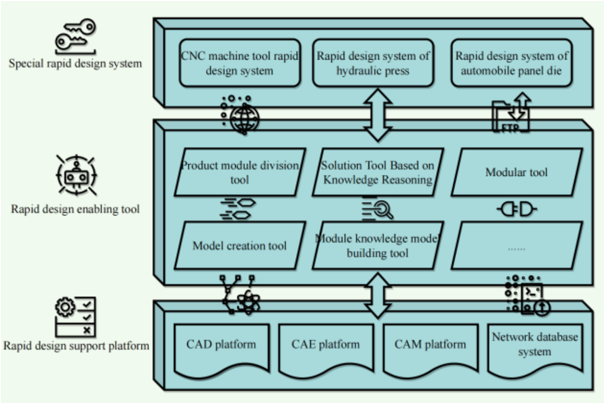

Figure 2: Functional hierarchy of rapid design software tool set.

Through the secondary development of the platform software, it can be extended to a special development tool for a certain type of product to achieve a small range of versatility. As a unit technology tool for rapid design on the general platform, this software can be used to complete the task of a certain stage of product design.

The mathematical description of this problem is: let $P=\{P_i\}_{i=1}^{N}$ be two corresponding point sets (the number of points in the point set is n). That is, for any point P_i, the transformed point Q_i should be RP_i+T in the ideal situation. However, due to the influence of noise interference and measurement data error, the error measurement function is as follows in order to better describe this problem:

$$E=\frac{1}{N}\sum_{i=1}^{N}\left\|Q_i-RP_i-T\right\|^2 \tag{1}$$

The solution that minimizes the value of the above error measure function is the rigid body transformation parameter to be solved. There are many methods to minimize the objective function, such as the relatively mature Newton iterative method, quaternion method, orthogonal matrix method, singular value decomposition method and dual quaternion method.

Translate the feature point set to separate the rotation and translation parts, and facilitate the calculation of R and T. Order:

$$P'_i=P_i-\frac{1}{N}\sum_{i=1}^{N}P_i \tag{2}$$

$$Q'_i=Q_i-\frac{1}{N}\sum_{i=1}^{N}Q_i \tag{3}$$

Then the minimum error function can be converted into:

$$F_{(R,T)} = \min \frac{1}{N} \sum_{i=1}^{N} \left\| P'_i - (RQ'_i) \right\|^2 \tag{4}$$

Then the rotation matrix and translation vector are:

$$R = UV^T \tag{5}$$

$$T = \frac{1}{N} \sum_{i=1}^{N} Q_i - R \frac{1}{N} \sum_{i=1}^{N} P_i \tag{6}$$

The scores of each unit are distributed as follows: complex surface modeling 15%, parametric and variable parts 15%, model and scene rendering 20%, animation production 20%, assembly and motion simulation 20%, file management and format conversion 10%, and objective problem unit 20%. As shown in Table 1.

Evaluation content	*Skill requirements*	*Relevant knowledge*	*Point decomposition*
Complex surface modeling	Complex surface modeling	Complex surface modeling method	5%
Parametric and variable design technology of parts	Part parameterization	Parameterized realization method of parts	5%
Model and scene rendering	Skill of surface texture pasting	Rendering properties and operations of	4%
	Skills of scene rendering	Scene light source application	4%
Animation production	Animation making and playing skills	Scene light source application	8%
Assembly simulation	Implement assembly simulation	Realization method of mechanism motion simulation	8%
Graphic file management	Graphic file management	Drawing file operation commands	4%
	Data conversion skills	Graphic file format and conversion	6%

Table 1: Measuring Point Table of Industrial Product CAD Skills Test Score.

3.3 CAD Model Based on STL Angular Mesh

Generally, CAD models are divided into two-dimensional CAD models and S-dimensional CAD models. Two-dimensional CAD models generally regard the engineering design drawings of products as a collection of geometric elements such as points, lines, circles, arcs, etc. Among them, product, module and sub-module are a group of concepts with relative inheritance relationship. For the sub-module of product module, it can be regarded as a modular product, with its own independent module system and complete modular data model information. Therefore, a unified data model can be established for products, modules and sub-modules, that is, the module data model is shown in Figure 3.

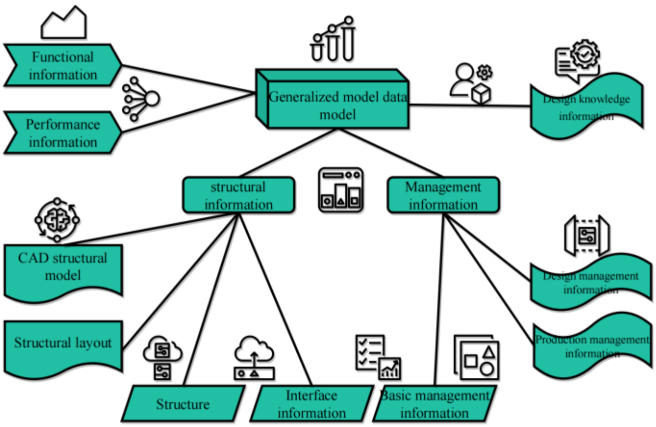

Figure 3: Information composition of generalized model data model.

In the process of software system development, in order to find the initial state and termination state of the design task and determine the modeling of the functional description of user requirements, it is necessary to establish the mapping of requirements to the design and development system through user requirements analysis. According to the requirements characteristics of product users, the mapping model will be established according to the specific requirements summarized and confirmed during the system design.

Let segment $P=\{pi\}_{i=1}^{Np}$ be the original measurement point cloud, and segment $X=\{x_i\}_{i=1}^{Nx}$ be the STL model data set of the target CAD model. This set X contains N_x triangular meshes, of which X_i respectively represent the H vertices of the $X_i=\{C_{i0},C_{i1},C_{i2}|n_i\}$,$C_{i0},C_{i1},C_{i2}$ king corner mesh, and n_i is the H corner mesh. Firstly, and calculates the point X_i which is closest to pi on t_i as the corresponding point.

The plane equation of M can be obtained from the normal vector n_i of M and a point x_{i0} on M as follows:

$$n_i \cdot \overrightarrow{C_{10}P}=0 \tag{7}$$

That is,

$$A(X-X_{i0})+B(y-y_{i0})+C(z-z_{i0})=0 \tag{8}$$

If the vertical foot is inside the triangular grid X_i, then the point X_i on P_i which is closest to t_i is the vertical foot, otherwise, t_i is on the vertex or edge of X_i. Such as the sum of internal angles, the same direction method, the center of gravity method and so on.

Get the change value of the parameter vector of the rigid body transformation of the adjacent two iterations, $\Delta q_k = \Delta\left[R(qk)\middle|\Delta T(qk)\right]$, here are

$$\Delta R(qk) \approx R(q_{k+1}) / R(q_k) \quad (9)$$

$$\Delta T(qk) \approx T(q_{k+1}) - T(q_k) \quad (10)$$

$$C_p = \frac{1}{N}\sum_{i=0}^{N}(P_i - \overline{P})(P_i - \overline{P})^T \quad (11)$$

Then solve the above equation to minimize the value, and record it as

$$(q, d) = M(P, Q) \quad (12)$$

Where M represents the minimization operation; d is the corresponding root mean square error, and item $d = E(q); q$ is the rigid body transformation vector obtained by the minimization operation, that is, $q = \left[R(q)\middle|T(q)\right]^T, R(q)$ represents the optimal rotation, and $T(q)$ is the optimal translation vector.

The rigid body transformation parameters calculated by the algorithm are applied to the original measurement point cloud, and are recorded as $q(P)$. This operation is performed every time in ICP algorithm iteration until a set convergence criterion is met.

$$u_p = \frac{1}{Np}\sum_{i=0}^{Np}, u_q \sum_{i=0}^{Nx} q_i \quad (13)$$

Use the center of gravity obtained in (13) to calculate the cross-covariance matrix of point set P and Q:

$$\sum_{pq} = \frac{1}{Np}\sum_{i=0}^{N_x}\left[(p_i - u_p)(q_i - u_q)^T\right] = \frac{1}{Np}\sum_{i=0}^{N_x} - u_p u_q \quad (14)$$

The whole process of estimating rigid body transformation parameters is a strict mathematical minimization process, which must include:

$$d_k \le E(q_k) \quad (15)$$

Based on the above derivation, it can be concluded that:

$$0 \le d_{k+1} \le E(q_{k+1}) \le d_k \le E(q_k) \quad (16)$$

4 RESULT ANALYSIS AND DISCUSSION

The software system adopts the object-oriented programming idea to carry out the overall system architecture and module design, and uses OpenGL to carry out the simple interactive operations of Wang Wei, such as display, rotation, zoom and translation, on the point cloud and the STLH angular mesh model. In addition, this system is mainly based on the algorithm development of an Open-Source Computer Vision Library (OPENCV). The library is composed of many C functions and C++classes. It implements a large number of APIs for matrix theory, computer vision and other related algorithms, with high efficiency. CAD model display and matching error data output. In order to verify and evaluate the performance of the algorithm proposed in this paper. After completing the above series of operations, we obtained all the data required for the simulation experiment, and then used these data to carry out the registration experiment respectively, and tested five-point cloud and CAD model registration algorithms. The experimental results of simulation experiment 1 are shown in Figure 4 and Table 2.

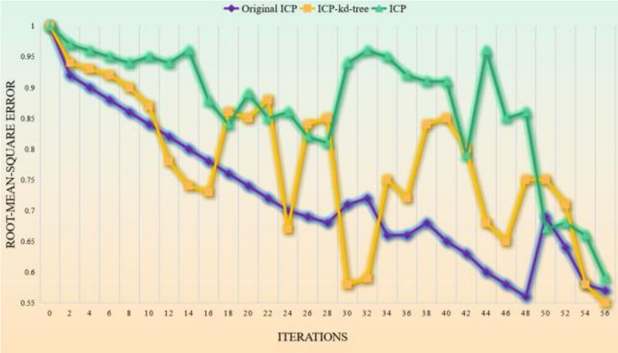

Figure 4: Simulation experiment 1 iterative curve of registration algorithm.

Registration algorithm	*Iterations*	*Root-mean-square error*	*Matching time*
Original-ICP	66	0.0526	44.66
ICP-kd-tree	62	0.0265	30.25
ICP	57	0.0211	38.15

Table 2: Simulation Experiment 1 Matching Results.

As shown in the chart, the characteristics of the results of all measurement experiments are consistent with those of simulation experiments.

It uses a data structure called K-D tree to manage the point cloud, which improves the registration efficiency. Under the same initial conditions, the ICP-STL registration algorithm can achieve a registration accuracy of 0.0077 wake-up, which is almost half that of the ICP registration algorithm based on KD-tree (0.01), and the registration time is much less than that of ICP registration algorithm and ICPP registration algorithm based on K-D-tree. Figure 5 shows the iterative curve results of the registration algorithm in measurement experiment 2.

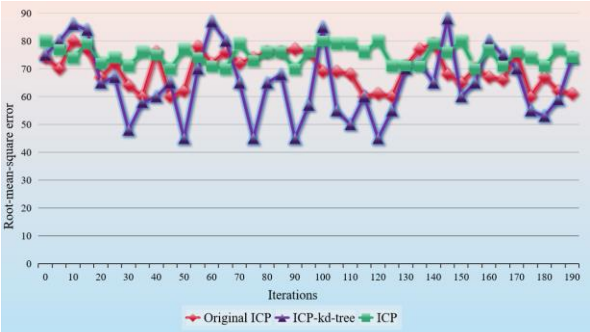

Figure 5: Measurement experiment 2 iterative curve of registration algorithm.

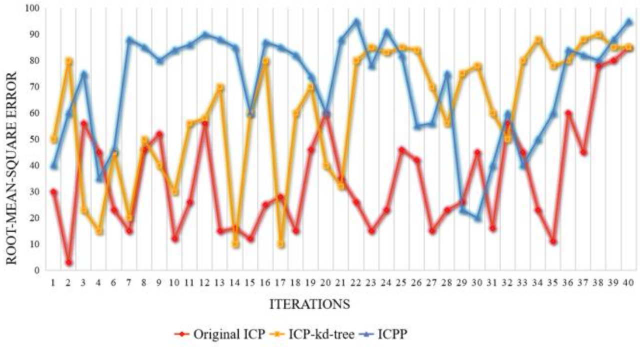

Figure 6: Comparison of iterative curves of original ICP and Ori-ICP-DAF registration algorithms in additional experiment 1.

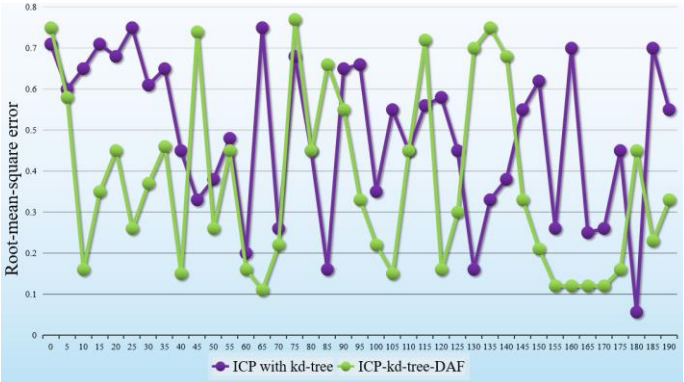

Figure 7: Comparison of iterative curves of ICP with kd-tree and ICP-kd-tree-DAF registration algorithms in additional experiment 2.

Figure 6 and Figure 7 compare the original ICP and Ori-ICP DAF registration algorithms in the additional experiments. Perhaps, we can apply this dynamic adjustment factor to other ICP series iterative algorithms to improve their convergence speed.

Under the policy of "mass entrepreneurship, mass innovation" and "Made in China 2025", China's industrial product design keeps pace with the world, and the domestic CAD competition gradually integrates with the world skills competition. The introduction of the mechanical design skill standard in the World CAD Competition, the formulation of the identification standard for CAD technicians in computer-aided design, and the launching of CAD competitions have played a guiding and exemplary role in the mechanical CAD education of CAD practitioners in various colleges and enterprises across the country. Through the competition, we will improve the CAD level of Jiangsu Province, cultivate a team of CAD high-skilled and compound innovative talents in line with the World Skills Competition, and improve the independent innovation ability of enterprises in Jiangsu Province.

5 CONCLUSIONS

This paper mainly discusses three aspects of Autodesk Inventor software learning, product design and independent innovation in the CAD skill competition of industrial product design, and introduces the preliminary learning, advanced learning and skilled application methods of software in detail. By mastering the creation of three-mode model and the simulation modeling of excellent award-winning design products, we can design simple products. On the basis of studying the basic principle of rapid design of mechanical products, a rapid design technology system framework based on modular design technology, which integrates intelligent design technology and computer-aided technology, is established, and the secondary development environment of CAD software of the system framework is studied. Based on this, this paper proposes a dynamic adjustment factor-dynamic adjustment of rigid body transformation parameter factor, which is added to the ICP algorithm based on STL blue angle grid, so that each iteration of point cloud rigid body transformation can realize overtravel transformation along the original trend, so that more effective corresponding points can be searched in the next iteration, so as to increase the iteration step and realize the fast convergence of ICP algorithm. Finally, compare the design innovation and the domestic and international CAD skill competitions to make contributions to the selection of CAD skilled talents for the society.

6 ACKNOWLEDGEMENTS

This work was supported by key R&D and promotion projects (scientific and technological research) projects in Henan Province: Research on the Application of Information Space Visualization Technology in the Protection of Intangible Cultural Heritage; Education and Teaching Reform Research and Practice Project in Zhengzhou University of Aeronautics: Research on the value of aesthetic education and its realization path in ideological and political education in universities(zhjy——104); Education and Teaching Reform Research and Practice Project in Zhengzhou University of Aeronautics: infiltrate、infiltrate、Innovation——The construction and practice innovation of art design history theory curriculum under the view of history education (No.zhjy22-13).

Yuanyuan Chai, https://orcid.org/0000-0002-8086-2078
Qiang Li, https://orcid.org/0000-0002-3134-5429

REFERENCES

[1] Andrade, J.-P.; Stona, D.; Bittencourt, H.-R.; Borges, G.-A.; Burnett, L.-H.; Spohr, A.-M.: Effect of different computer-aided design/computer-aided manufacturing (CAD/CAM) materials and thicknesses on the fracture resistance of occlusal veneers, Operative dentistry, 43(5), 2018, 539-548. https://doi.org/10.2341/17-131-L
[2] Chhetri, S.-R.; Faezi, S.; Al, F.-M.-A.: Information leakage-aware computer-aided cyber-physical manufacturing, IEEE Transactions on Information Forensics and Security, 13(9), 2018, 2333-2344. https://doi.org/10.1109/TIFS.2018.2818659
[3] Chu, C.-H.; Chang, W.-C.; Lin, Y.-I.: An exploratory study on computer-aided affective product design based on crowdsourcing, Journal of Ambient Intelligence and Humanized Computing, 11(11), 2020, 5115-5127. https://doi.org/10.1007/s12652-020-01821-6
[4] Dokken, T.; Skytt, V.; Barrowclough, O.: Trivariate spline representations for computer aided design and additive manufacturing, Computers & Mathematics with Applications, 78(7), 2019, 2168-2182. https://doi.org/10.1016/j.camwa.2018.08.017
[5] Hao, M.; Ni, T.: Color Harmony Algorithm in Computer Aided Industrial Design, Computer-Aided Design, 19(S4), 2022, 36-45. https://doi.org/10.14733/cadaps.2022.S4.36-45
[6] Lee, S.; Hong, S.-J.; Paek, J.; Pae, A.; Kwon, K.-R.; Noh, K.: Comparing accuracy of denture bases fabricated by injection molding, CAD/CAM milling, and rapid prototyping method, The

journal of advanced prosthodontics, 11(1), 2019, 55-64. https://doi.org/10.4047/jap.2019.11.1.55
[7] Rawi, I.; Karuppannan, G.; Ghani, K.: 2D CAD engineering drawing for industrial design: furniture and products designed by students, Int. J. Acad. Res. Bus. Soc. Sci, 10(2), 2020, 847-859. https://doi.org/10.6007/IJARBSS/v10-i2/7015
[8] Saleh, B.; Rasul, M.-S.; Affandi, H.-M.: The Conceptual Framework of Quality Product Design Based on Computer Aided Design (CAD), Creative Education, 9(14), 2018, 2311. https://doi.org/10.4236/ce.2018.914171
[9] Trzepieciński, T.; dell'Isola, F.; Lemu, H.-G.: Multiphysics modeling and numerical simulation in computer-aided manufacturing processes, Metals, 11(1), 2021, 175. https://doi.org/10.3390/met11010175
[10] Tsujimoto, A.; Barkmeier, W.-W.; Takamizawa, T.; Latta, M.-A.; Miyazaki, M.: Influence of thermal cycling on flexural properties and simulated wear of computer-aided design/computer-aided manufacturing resin composites, Operative Dentistry, 42(1), 2017, 101-110. https://doi.org/10.2341/16-046-L