Hindawi

Retraction

Retracted: Application Analysis of 3D Printing Technology in Design Field: Taking Shoe Design as an Example

Scientific Programming

This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

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Research Article

Application Analysis of 3D Printing Technology in Design Field: Taking Shoe Design as an Example

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The development of 3D technology has brought opportunities and challenges to the footwear industry because people's living standards have been improving due to economic development, and people have higher requirements for the design of fashion shoes and boots. The use of 3D printing technology in the design of fashion shoes and boots can enable faster molding of footwear products, enrich the shape of footwear, and meet people's aesthetic needs for fashion shoes. In this paper, we firstly describe the advantages of 3D printing molding shoe models and then use 3D laser foot scanning and measuring instrument to scan and obtain the cloud map of shoe lasts and foot-related data. Secondly, we realize the digital management of shoe lasts by establishing the database of solid models. On this basis, we apply the technology of least squares support vector machine improvement algorithm to make partial modifications to the lasts according to the need to leave the appropriate helper and foot lining degrees. Finally, based on this technology, we apply the least squares support vector machine improvement algorithm technology to make partial modifications to the last shape according to the need for appropriate helper and foot lining degrees to realize the process of shoe last redesign. The last model and role model can also be produced by 3D printing technology, which can be used as a mold to facilitate the processing of the cut last 2D unfolding material for shoe and boot production later. Therefore, the article studies and analyzes the design and manufacturing process of digital shoe lasts based on individual foot shape and uses CAD/CAM technology to realize the digitalization of shoe last design.

1. Introduction

With the continuous improvement of people's quality of life, people's requirements for shoes and boots are getting higher and higher, and people are also putting forward higher requirements for the design of fashionable shoes [1]. With the development of 3D printing technology, people recognize the importance of 3D printing technology, and the level of recognition is also increasing. 3D printing technology can play an important role in the field of footwear [2].

At present, the shoe lasts made in large quantities by shoe-making enterprises and factories are designed and made according to the relevant shoe last models and design standards. The relevant data given in these last design standards are mainly formulated according to statistical laws

and experience [3, 4, 5]. This results in the same model of shoes and boots made from the same model of shoe lasts. Some people wear them to fit while others wear them not to fit. Long-term wearing of shoes that do not fit the physiological condition of the human foot will not only produce a sense of discomfort but also seriously affect the development and formation of the bones of the human foot, and for people with foot diseases, unsuitable shoes and boots may even worsen their symptoms and bring serious consequences [6]. For athletes and other special groups, unsuitable shoes may significantly affect athletic performance. In addition, shoes and boots are gradually becoming a fashion trend, which is the presenting body and carrier of beauty. When designing shoe and boot styles, it is necessary to meet not only their comfort but also the demand for aesthetic

presentation when they are produced as daily-use products [7, 8], but there is still a lack of ways to quantify the beauty in the current shoe last production, which makes it objectively difficult to achieve the ideal design. With the gradual improvement of people's living standard, there are correspondingly higher requirements for shoes and boots. Fashion and personalization have become a development trend, and the reasonable use of 3D technology can make them more perfect.

3D printing technology originated in the United States in the 1980s. At the beginning of this century, with the development of mainstream technologies such as stereo light-curing molding, selective laser sintering, and fused filament deposition modeling, 3D printing technology gradually matured [9, 10]. In 2007, Objet Geometries launched the Connex500TM system that supports the simultaneous printing of multiple model materials. Objet Geometries launched the Connex500TM system, which supports the printing of multiple model materials at the same time. Currently, 3DSystems, Stratasys, HP Inc., MakerBot, EOS, SLM Solutions in Germany, and Objet in Israel are at the forefront of this field [11, 12]. In developed countries such as Europe and the United States, 3D printing technology has been widely applied in various fields; with the development of 3D printing technology in China, it has been applied in various fields, such as biology, medicine, national defense, aerospace, education, culture and creativity, architecture, clothing, food, and has shown superior performance and good market prospects [13].

Compared with traditional production methods, 3D printing can significantly shorten the production cycle, which is conducive to the convenient and efficient development of products. However, on the other side of the coin, we should also see that after the rapid development of 3D printing in the past few years and market pursuit, a series of problems have emerged, such as high costs, bottlenecks in mass production, restrictive technology and materials, and the proliferation of capital and market hype, all of which have yet to return to a rational and pragmatic attitude.

2. Related Progress

The use of 3D printing technology on the upper of sports shoes is still very limited, but this technology is an urgent challenge in the field of sports shoe production, and Nike is at the forefront for the time being. As the first sports brand to introduce 3D printing technology, Nike developed the first generation of 3D printed soccer shoes, "new Nike Vapor LaserTalon" and rugby shoes "Vapor Laser Talon" in 2013. After that, Nike launched the "Vapor Carbon 2014" elite running shoe and the "VaporHyperAgility" soccer shoe [14, 15]. It provided the famous American sprinter Allyson Felix with a 3D printer soccer shoe. Before the Rio Olympics, Nike developed an exclusive pair of high-performance spikes, "Zoom Superfly Flyknit" for the famous American sprinter Allyson Felix to meet her competition need, which eventually helped the "female flyer" win the Olympic championship [16]. In 2016, Nike announced a strategic partnership with printing giant Hewlett-Packard to use the HPJet Fusion3D printer to improve the efficiency of shoe prototypes and reduce costs.

In 2018, Nike even broke new ground with the launch of the Flyprint running shoe, which differs from its own and other brands' previous 3D printed sneakers in that it uses solid deposition modeling (SDM) technology to create the upper [17].

Adidas released its 3D printed running shoe "Futurecraft 3D" in 2015, and its limited edition "3D Runner" went on sale at the end of 2016. This running shoe can be tailored to the user's foot structure and personal sports habits [18, 19]. The shoe can be tailored to the user's foot structure and personal sports habits, with a "Primeknit" upper woven technology and an outsole and hollow midsole made of 3D printing technology.

Following the wave of 3D printing technology, Andromeda also launched a limited-edition trainer, "UA Architech," in March 2016 and a pair of 3D printed sneakers for American swimmer Michael Phelps in the same year [20]. In 2017, the company launched a new generation of 3D printed sneakers, "The ArchiTech Futurist," which features a 3D printed midsole with an interlocking grid structure that provides a "dynamic stability platform" for better stability and cushioning and a one-piece, seamless upper for a superior fit. Reebok uses 3D drawing technology to cleanly and accurately "draw" shoe components at the 3D level. This proprietary layering technology provides for the efficient, fast, and straightforward creation of personalized footwear without the need for molds. The sneaker features a high-rebound outsole with 3D printed laces that integrate the outsole with the upper for all-around foot comfort and responsive energy feedback [21].

New Balance improved its 3D printed concept sneaker "Fresh Foam Zante" in April 2016, rebranding it as the "Zante Generate" for a limited public release.

In early 2018, Anta also introduced Uniontech printing equipment, mainly used for research and development of footwear products. In June 2018, Li Ning released the latest version of its "Reignited" series at Paris Fashion Week, with its skeleton sole made of 3D printing technology and transparent plastic for the outer layer of the upper. The use of both materials is just right, creating the impression of fashion, technology, and youthfulness [22, 23].

In addition to major sports shoe brands at home and abroad, there are many related organizations at home and abroad conducting similar research, including many companies and brands that develop niche professional sports products are also trying their best to use 3D printing technology in the field of footwear design and production as early as possible.

2.1. Advantages and Limitations of 3D Printing Technology in Athletic Shoe Design and Manufacturing. 3D printing technology is a typical "additive manufacturing." It can be highly efficient, energy-saving, distributed, personalized, on-demand production mode manufacturing products, changing the previous large-scale and centralized industrial pattern, which is conducive to reduce the labor cost of low-

end manufacturing industry and the rapid development of innovative small enterprises [24]. At the same time, 3D printing technology circumvents the complex and time-consuming mold development and manufacturing process. With the further development of this technology, the printing efficiency and quality are bound to improve, so the manufacturing cycle of sports shoes will be further shortened, which also means that the speed of product iteration will be further enhanced.

3D printing technology has been a hot topic in design and manufacturing in recent years, bringing together many specialized research institutions and talents. The technology associated with it is constantly evolving. For example, before Nike's Flyprint running shoes, almost all 3D printing was focused on athletic shoe soles. However, they used solid deposition modeling manufacturing to create the idea of translating athletes' foot shape and movement data into textile geometry and collecting data through computational design tools to achieve the ideal material ratios [25]. The data was also collected through computational design tools to achieve the ideal material ratios. The performance of the shoe can also be adjusted at a later stage by adding or subtracting "warp and weft yarn" as needed, and the printing process is about 16 times more efficient than previous manufacturing processes.

With in-depth research of 3D printing technology, it is believed that, with its new technology and techniques, some difficulties in the manufacturing of sports shoes can be solved and optimized to help achieve better product performance and appearance design effects [26].

3. 3D Advantages of Printed Modeling Technology for Shoe Modeling

In the production of shoes and boots, the traditional production process is mainly design, pattern making, cutting, sewing, and molding. The entire book production process takes much time and is very complicated. Combining 3D modeling technology and 3D printing technology can quickly realize the initial production of molds and verify the effect, thus reducing the time spent on shoe production, improving the competitiveness of shoe and boot enterprises in the fierce market competition, and promoting the further development of related enterprises [1, 9, 27].

(2) Advantages of shoe modeling have great advantages in terms of freedom. The use of 3D software and technology for shoe modeling allows creating and changing the shape of the shoe or boot in accord with the design requirements. Some products have complex mold shapes before production, and 3D modeling technology can be used to better design them. The 3D modeling technology is needed to integrate fashion elements faster and better [13, 28].

When making fashion shoes and boots, it is difficult to combine some traditional shapes by traditional hand-design methods, and polygonal cross-sectional structures cannot be used as models for making shoes. In addition, shoes are made from open panels, which are prone to the problem of unevenly combined shapes and, therefore, poor integration of geometry [3]. Thus, processing technology seems to play a

great role in the production of shoes in modern society and is a realistic and important driving force in its development and advancement, which can effectively drive the industry forward.

3.1. Least Squares Support Vector Machine Improvement Algorithm. SVM is essentially a machine learning-based classification model [7], which is widely used in the field of statistical classification and regression analysis [29]. It achieves the classification of a dataset by finding a hyperplane that satisfies the classification requirements so that the different types of points of the selected training set are as far away as possible relative to the classification plan (see Figure 1).

The least-squares support vector machine (LS-SVM) algorithm is a variation of the standard SVM, which converts the SVM to solve a linear system of equations, avoiding the use of insensitive loss functions and greatly reducing the computational complexity.

The specific derivation of the LS-SVM algorithm is as follows.

Given N training samples, where x_i is the n-dimensional training sample input and y_i is the training sample output, in this paper, $(x_{i1}, x_{i2}, x_{i3}, y_i)$, where x_{i1} denotes the first variable factor in the i-th training sample, x_{i2} denotes the second variable factor in the i-th training sample, and x_{i3} denotes the second variable factor in the i-th training sample.

The objective optimization function of the LS-SVM algorithm is

$$J_1(w, e) = \frac{\mu}{2}w^T w + \frac{1}{2}\gamma \sum_{i=1}^{N} e_i^2,$$

$$\text{s.t. } y_i = w^T \phi(x_i) + b + e_i; \quad i = 1, \ldots, N, \tag{1}$$

where $\varphi(\ )$ is the kernel space mapping function, w is the weight vector, e_i is the error variable, b is the bias, and μ and γ are adjustable parameters. To solve for the minimum of the function, construct the Lagrange function:

$$L = J_1(w, e) - \sum_{i=1}^{N} \alpha_i \{w^T \phi(x_i) + b + e_i - y_i\}, \tag{2}$$

where α_i is the Lagrangian multiplier.

The partial derivative of equation (3) yields

$$\frac{\partial L}{\partial w} = 0 \longrightarrow w = \sum_{i=1}^{N} \alpha_i \phi(x_i) \frac{\partial L}{\partial b} = 0 \longrightarrow \sum_{i=1}^{N} \alpha_i = 0,$$

$$i = 1, \ldots, N \frac{\partial L}{\partial e_i} = 0 \longrightarrow \alpha_i = \gamma e_i, \tag{3}$$

$$\frac{\partial L}{\partial \alpha_i} = 0 \longrightarrow w^T \varphi(x_i) + b + e_i - y_i.$$

By eliminating w and e, the solved optimization problem is transformed into solving the linear equation:
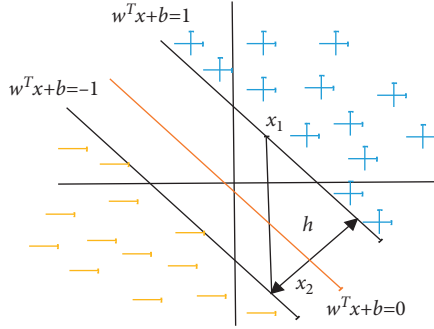
FIGURE 1: Fundamentals of support vector machines.

$$\begin{bmatrix} 0 & I_v^T \\ I_v & \Omega + \dfrac{1}{\gamma} I_N \end{bmatrix} \begin{bmatrix} b \\ \alpha \end{bmatrix} = \begin{bmatrix} 0 \\ y \end{bmatrix}, \tag{4}$$

where

$$\begin{aligned} y &= [y_1; \ldots; y_N], \\ I_v &= [1; \ldots; 1], \\ \alpha &= [\alpha_1, \ldots, \alpha_N], \\ \Omega &= \phi(x_i)^T, \\ \varphi(x_i) &= K(x_i, x_l)i, \\ l &= 1, \ldots, N. \end{aligned} \tag{5}$$

The LS-SVM for function estimation is obtained by solving equation (5) and then

$$y(x) = \sum_{i=1}^{N} \alpha_i K(x, x_i) + b, \tag{6}$$

where $k(x, x_i)$ is the kernel function. The commonly used kernel functions are mainly polynomial, RBF (radial basis), Sigmoid, and so on. The radial basis kernel function is generally used:

$$K(x_i, x_j) = \exp\left(-\frac{\|x_i - x_j\|^2}{2\sigma^2} \right) \sigma > 0. \tag{7}$$

The LS-SVM based on the radial basis kernel function needs to determine two parameters, penalty factor γ and kernel parameter σ [8]. The kernel parameter σ is a self-contained parameter of the radial basis kernel function, which mainly determines the actual size of the dimensionality of the resulting effect after mapping. The larger σ is, the faster the weight of the higher-level features decay, which is equivalent to mapping to a low-dimensional subspace; conversely, the smaller σ is, the more linearly divisible the results of arbitrary data mapping will be. The choice of γ, mainly for the segmentation process, may appear in the singularity of the introduction of soft interval hyperplane and determine the degree of tolerance for the accuracy of the segmentation surface. γ is larger, indicating that the segmentation process to select the support vector error

tolerance increases, resulting in inaccurate segmentation; otherwise, it may cause the segmentation not to be completed.

For the determination of γ and σ, the traditional algorithm generally uses the grid search method. Herein, we improve the genetic algorithm to optimize the selection of parameters γ and σ and use the 3-fold cross-validation classification accuracy as the fitness function. The value range of γ is (0.01 to 100), and the value range of σ is (0.01 to 100).

The genetic algorithm (GAA) is a heuristic algorithm that draws on natural selection and natural genetic mechanisms in biology and is more convenient, more robust, and easier to process in parallel than traditional methods such as a grid search. When dealing with the two model parameters γ and σ of the support vector machine, we first initialize the model parameters, set the binary code, randomize the initial population of the model parameters, and train the support vector machine model. The genetic algorithm is the maximization of the fitness function for the optimization, while the support vector machine model parameter selection is a minimization optimization problem, so the following conversion is made:

$$\text{Fit} = \begin{cases} C_{\max} - f(x), \\ 0. \end{cases} \tag{8}$$

After the fitness function is calculated, the global optimal solution is judged, and if the condition is satisfied, the determined parameters γ and σ are incorporated into the support vector machine model training. Otherwise, population regeneration, selection, crossover, and variation are performed iteratively until the termination condition is satisfied, and the computational effects are compared in Table 1.

3.2. Digital Shoe Last Design and Manufacturing Process. The shoe last is complex. Multidirectional irregularly twisted free-closed surface with long edge lines, many feature areas, and drastic curvature changes [2] causes difficulties in its design process, including (1) poor control of the external shape and poor density and (2) being not conducive to the rapid local modification of the last and not convenient to design personalized lasts according to the special foot shape. Therefore, the computer-aided design (CAD) and computer-aided manufacturing (CAM) design of shoe lasts have become a problem and a hot issue for discussion in recent years. The design and manufacturing process of shoe lasts is synthesized from the characteristics of shoe lasts and the experience of the traditional shoe manufacturing process. This paper summarizes the design and manufacturing process of shoe lasts into the following steps:

(1) Take human foot as the design prototype: first use 3D laser scanning measuring instrument to measure the human foot shape data, and after data processing, form the shoe last cloud model to complete the digitalization of human foot.

TABLE 1: Comparison of classification results.

Prediction algorithm	$y. \sigma$ method	Parameter value	Correct rate (%)
Least squares support	Grid search method	1,78	85.2941
Vector machine	Genetic algorithm	1.2,76	92.6471
BP neural network			60.2941

(2) After modifying the human foot model according to the demand, the data will be transferred to CAM to generate the CNC program and transferred to the cutting machine control computer. The vibrating cutting machine will be used for cutting, and the 2D unfolded shoe last section can be processed.

(3) Various file formats (e.g., stud, its file formats) are generated by CAD. The shoe lasts can be cut out by using advanced manufacturing technology CAM, or the shoe last models can be made by 3D printers, according to which the corresponding shoe last molds are made and the molds are used to reform the shoe lasts.
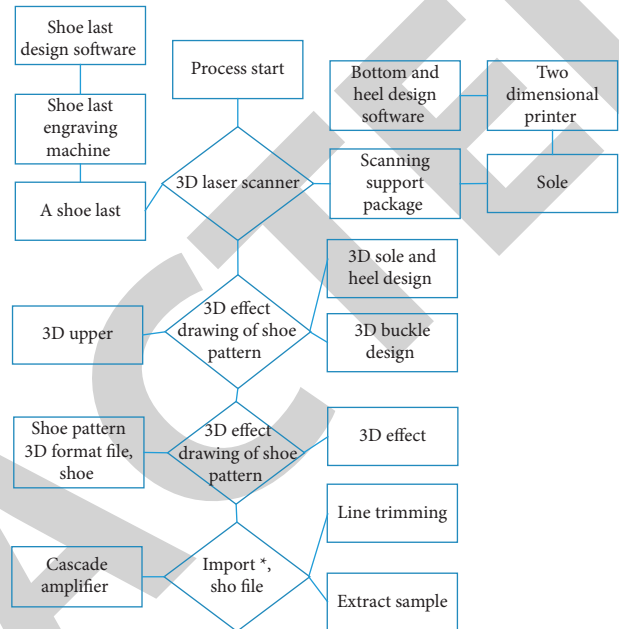
The specific design steps are shown in Figure 2.

3.3. Measurement Methods and Data Processing.

The process from the human foot to the shoe last belongs to a kind of reverse engineering; that is, the human foot is used as the design object, and the last is designed and manufactured in turn to obtain the shoe last [4]. In this process, there are two key technologies: (1) the method of obtaining data related to the surface of a human foot; (2) the technology of constructing the surface of the shoe last based on the human foot data, and the need to solve the technical problem of transferring the raw data obtained from the measurement to the CAD/CAM system. At present, there are two measurement methods for foot geometry related data: contact probe measurement (such as mechanical measuring instrument CMM) and noncontact probe measurement (such as photoelectric scanner and laser scanner) [5, 6]; considering the peculiarities of human foot muscles, it is more appropriate to use laser scanner measurement, which is characterized by fast scanning speed and convenient measurement of foot size and can carry out intensive scanning measurement of human foot surface. The laser scanner is characterized by fast scanning speed, convenient foot size measurement, and intensive scanning measurement of the human foot surface, thus obtaining many "point cloud" raw data value points. In data processing, firstly, the useless points and bad points in the original data are judged and eliminated according to experience; secondly, the data point files are programmed to extract the useful data required for CAD modeling and handed over to the CAD system for curve, surface, and solid modeling; and finally, the CAD digital model of the prototype is obtained, as shown in Figures 3 and 4.
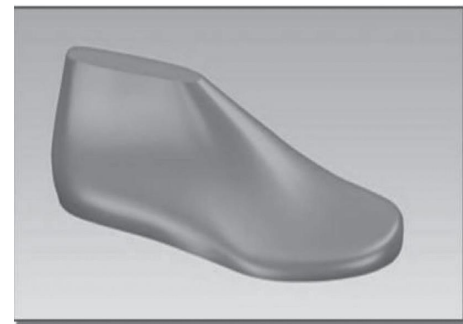
3.4. Shoe Last Modeling Design Analysis.

Analyzing the structure of the human foot, we can see that its palm surface is flat, but not completely flat, and the surface of the human foot is uneven and completely irregular. Then, as a model of the human foot, the surfaces on the last form are different

FIGURE 2: Digital shoe last design process.

FIGURE 3: Model of shoe last after data processing.

FIGURE 4: Adjustment of heel height and last centerline.

everywhere, and the curvature changes greatly. There are both smooth surface parts and sharp corners and edges, so it is a typical nonexpandable free-form surface. For such a complex form, obviously, if the geometric modeling is completely in accordance with the shape of the human foot [7], it is technically quite difficult and practically unnecessary, and the process can be appropriately simplified. In general, the length and girth of the human foot (generally the top to girth and the front tarsal girth) are the two main design control parameters of the shoe last. On this basis, for a definite human foot type, the changes of the last required by various shoe types are mainly based on the changes of last and heel height, as shown in Figure 4. These changes will cause the last surface to change, and the point line surface describing the last surface will change accordingly. Thus, toe type and heel height are determined as the main parameter variables. In modeling, the last surface can be divided into different surface pieces, such as the last sole surface, the front surface piece, and the back surface piece. After modeling them separately, each surface piece will be put together to form the last shape. In the design process, considering that the shoes will scrape the ankles, in order to produce shoes and boots later on the physical ankle without the friction caused by the heel of the shoe, the curvature and the helper's foot degree are designed for the heel of the last, and the heel curvature and the helper's foot line are modified according to the characteristics and needs of different people's feet, so that the appropriate curvature and helper's foot angle can be reserved [8], as shown in Figure 5. The 3D effect of the shoes obtained through the software is shown in Figure 5.

4. 3D Printing Performance

As shown in Figure 6, from the perspective of 3D printed footwear appearance and design, the postprocessing and beautification of the finished print effect is still relatively limited, generally using sanding and color spraying to postprocess the product, but in the color and texture, texture effect processing is still poor, and richness is very insufficient. Although the current multicolor multimaterial printing can be achieved, the number of colors and material types of consumables is still relatively limited, often high color saturation, completely unable to meet the performance of the various subtle intercolor, multicolor, spot color, and popular colors required for sports shoes products. Of course, complex color effects and pattern effects are more difficult to achieve. In addition, due to the limited materials and melting layered way, resulting in 3D printed products texture, the performance is also relatively monotonous, unable to simulate the texture of various shoe materials, such as hardware accessories, textiles or leather, and other materials of various decorative processes, the lack of texture changes. Therefore, how to print products on the exquisite postprocessing so that shoes present richer and more diverse visual effects to meet the diverse needs of the consumer market is also one of the problems to be solved.

As shown in Figure 7, 3D-aided design and printing technology can maximize individual requirements in terms of foot size, posture, and sport. As a result, athletic shoe

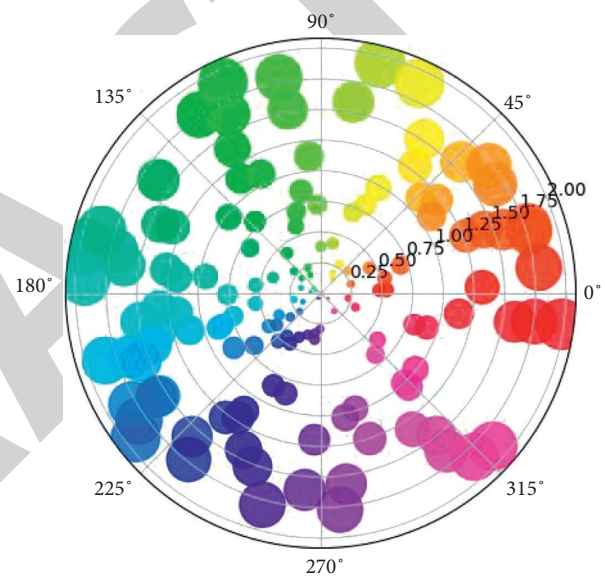Figure 5: 3D software to create shoes effect.

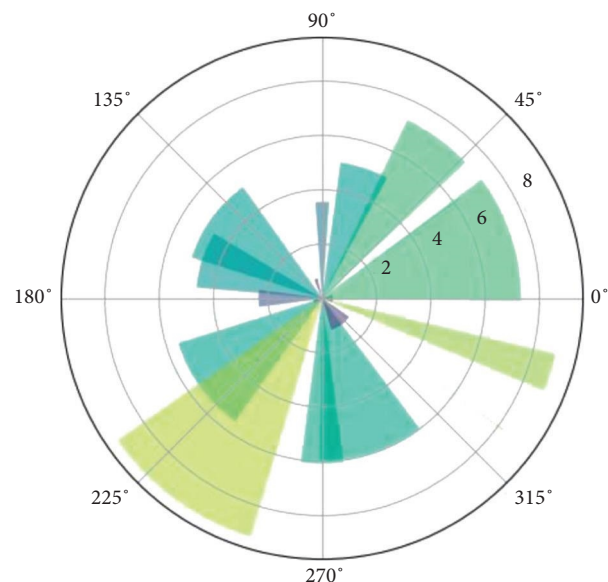Figure 6: Printed polarization angle of 3D.

Figure 7: 3D printing sector.

companies, which have always pursued the use of technology, are scrambling to introduce 3D printing technology to improve footwear performance and enhance athletic performance. However, in general, some challenges still need to be overcome.

5. Conclusions

The new manufacturing technology represented by 3D printing is making a far-reaching change to the traditional manufacturing industry model. It can help footwear designers more conveniently transform design ideas, greatly improve the efficiency of product design, greatly expand the creative space of footwear design, and quickly create product prototypes. The forms and structures that are difficult to manufacture by traditional forming methods are produced in an efficient and low consumption way to improve the original and innovative design, processing, and manufacturing mode and the ecological environment of the manufacturing industry.

Under the baptism of 3D printing technology, the sports footwear industry will also undergo significant changes in the original design, development, and production methods, which will be beneficial in the development of sports footwear products, product innovation, appearance design, and function research and development, as well as the development of customized services. It will help enterprises better adapt to the current consumption patterns and market trends of fast fashion, personalization, small batch, and diversification; promote the footwear enterprises in China to adapt to the design and manufacturing mode under the Internet + and big data model; meet the Internet marketing and the possible distributed production pattern in the future; and gradually cultivate and develop and grow their own brands.

With the in-depth development of 3D printing technology, inevitably, the categories of printing consumables, performance, print quality, process level, appearance effects, and other aspects will continue to improve, providing more possibilities for the development of various types of sports shoes products; better meet the performance requirements of shoes on printing materials; achieve more technological product performance and richer product effects.

Data Availability

The dataset used in this paper are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding this work.

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