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Research Article

Innovation Strategy of 3D Printing in Industrial Design Based on Vision Sensor

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3D printing is becoming increasingly integrated across all disciplines affecting traditional manufacturing. Traditional subtractive and isomaterial processing techniques make it difficult to process and manufacture complex structures such as spatial surfaces and complex cavities. Traditional processing and manufacturing processes are complex. Cumbersome clamps are also a drawback of traditional machining. Compared to traditional processing and manufacturing, 3D printing has significant advantages in manufacturing processes and manufacturing complex structures. Based on this, this paper studies the application of visual sensor 3D printing technology in industrial design and further studies the innovative free design methods under the implementation of 3D printing to provide a design basis for solving industrial product processing troubles and complex structures. This paper first provides a theoretical analysis of the combination of 3D printing of vision sensors and innovative design of industrial products. Next, take two classic industrial parts, a mechanical hydraulic valve block, and a crankshaft, as an example, and adopt an innovative and free design method to get an optimized pipeline of hydraulic valve blocks. The crankshaft molding structure integrated with the structure of the lightweight block demonstrates the superiority of 3D printing technology over the innovative design and manufacture of industrial products. Experiments have proved that the molding direction 1 consumes the least time and consumables (5 h 3 min, 24.44 m), but the inner channel is a blind hole, and it is difficult to remove the support after processing. The molding direction 2 consumes a little more consumable but not too much, but the channel supports are all easy to remove, and molding direction 3 has no advantage in all aspects. Research on industrial design innovation strategy of vision sensor 3D printing technology not only leads to the realization of vision sensor 3D printing technology and its equipment. It also provides a specific reference for the green and intelligent development of the future high-end equipment manufacturing industry.

1. Introduction

With the development and changes of the times and with the improvement of people's living standards, social needs have undergone great changes, and personalized needs have become the mainstream. 3D printing technology is gradually used in aerospace, automotive, consumer goods, cultural and creative, medical, construction, and education industries. For consumers, consumers are unwilling to "jump shirt," pursue individuality, and show themselves; in terms of manufacturing, differentiated operation has become one of the main competition strategies. Today's wide variety of small lot production and short cycle production need to realize continuous production in pursuit of the manufacturing industry. This not only meets the individual needs of our customers but also ensures high production efficiency in continuous production. Develop and apply 3D printing technology to meet the individual needs of the market, shorten production cycles, and achieve fast, low-cost personalized designs, small batches, multiple varieties, and continuous production.

In the specific manufacturing process, 3D printing is an additive manufacturing technology that uses three-dimensional sketches to create through continuous physical layers. As a technological means to lead the future, it can fundamentally change the traditional craftsmanship, complete the crafting with the aid of a computer, and form a solid molding technology by stacking the layers of practice. At present, 3D printing technology is more mature than in the past and still has a large potential for development. Under the background of the development of globalization and high-tech modernization, 3D printing has become a trend of industrial design and production and is widely used in the field of industrial design. Customizing your personal needs is no longer out of reach. 3D printing technology helps the designer's complete mold printing in hours. With this speed-up method, it is low cost, environmentally friendly, pollution free, and at the same time beautiful and exquisite production. And this method can meet the requirements of the designer while saving many raw materials, especially some precious and rare materials.

3D printing technology can realize free design and rapid prototyping, which will change production methods and lifestyle, and has a bright future. With the development of information technology, known as the symbol of the third industrial revolution, 3D printing technology featuring digitization, artificial intelligence, and the application of new materials has brought revolutionary changes to future product manufacturing [1]. Abbasi et al. studied the application of 3D printing technology in industrial product design and introduced the working principle of 3D printing technology and its application advantages in industrial product design, as well as the impact of the development of 3D printing technology on industrial product design [2]. The design of industrial products was discussed from four aspects: design ideas, design patterns, industrial designers, and product development patterns. Finally, the application limitations and prospects of 3D printing technology in industrial product design were further analyzed. However, in his research, the lack of experimental data leads to small differences in the sample set, which leads to inaccurate results [3]. Galaso et al. analyzed the impact of 3D printing technology on product design concepts, details, industrial processes, and models by comparing the new and old production methods. It is found that the product structure is no longer restricted by the traditional manufacturing process; the designer's ideas can rely on 3D printing technology to become a real product, which has spawned a group of independent designers and product design. 3D printing technology has shortened the time for product design and delivery. The development cost is lower, and the applicability of the product is stronger, so that a new manufacturing model can be formed. However, its overall research lacks data support, and more data is needed to support its conclusions [4]. The application status of 3D printing in the industrial design industry and the characteristics of 3D printing are analyzed and summarized; the impact of 3D printing technology on industrial design and manufacturing is discussed, and a new design and production process is proposed; and the future vision of 3D printing predictive analysis is carried out on the application in the field of industrial design. It is found that 3D printing technology has broken the original framework. Whether it is from industrial design thinking or production practice, it has brought new creative space and possibilities, but its research has not revealed the limitations of 3D printing in industrial design. It is not conducive to the final predictive analysis [5].

This article proposes a 3D printing-oriented industrial design concept with the aim of studying the application of vision sensor 3D printing technology in the industrial design and manufacturing industries and design methods without mechanical innovation under the influence of 3D printing. The purpose is to do practical value and applications in the manufacturing industry to enhance 3D printing technology of equipment, innovative research on new 3D printing concepts, industrial design ideas, and finally traditional industrial product design and 3D printing. Combined to enable interintegration of industrial design and new technologies and under the structure of industrial products that affect 3D printing technology, create innovative free design guidance.

2. Vision Sensor 3D Printing Innovation Strategy in Industrial Design

2.1. 3D Printing and Three-Dimensional Object Forming

2.1.1. The Way of Forming Three-Dimensional Objects. In popular terms, forming theory is a method of obtaining three-dimensional objects, and it is a scientific classification theory that studies the orderly forming of materials into specific shapes or special functions. From ancient times to the present, molding and manufacturing have run through the entire human history. Whether it is stone tools with simple molding techniques in ancient times; high-tech, modern machinery; or animals and plants that exist in nature, they can be summarized into the following four molding methods [6, 7].

(1) Subtractive Molding. It is mainly due to the use of certain technical means to remove excess material from most of the raw materials to form an orderly shape of the object. Although this technology is widely used in the field of industrial production, it also has various drawbacks and wastes of raw materials. At the same time, it is difficult to achieve automatic mass production of relatively complex items with this molding method, most of which require manual assistance.

(2) Compression Molding. In the past, when complex and precise products were required to be manufactured quickly, compression molding was used to complete them. Although this method can manufacture complex and precise objects, the choice of materials is subject to certain restrictions and restrictions. Materials that do not have plasticity cannot be used to make complex models using this molding method.

(3) Additive Molding. In the traditional pottery making process, the process of making mud embryos with mud sticks is the method of additive molding, which makes it easy to make and shape difficult-to-polymerize mud. 3D printing also uses additive molding technology. This realization of the process from scratch is the magical place of 3D printing [8, 9]. The complex three-dimensional object structure is transformed into a two-dimensional planar structure layer by layer, which not only saves raw materials but also makes the production process simpler.

(4) Growth Molding. Growth molding is a part of bionics, which refers to a molding method that uses bionic materials to imitate the growth of organisms in nature. It is a product

of the combination of biological sciences and manufacturing technology, which self-replicates through directional induction of cell differentiation to form objects with specific shapes and special functions. 3D printing in biomedicine is a manufacturing technology based on growth and molding.

2.1.2. The Basic Printing Process of 3D Printing. Although 3D printing contains a variety of different molding processes, the basic workflow is the same. As shown in Figure 1, the process of 3D printing starts with obtaining a three-dimensional model; after the model is processed, a file recognized by the printer is generated; and finally, the online printing is constituted by the process [10, 11]. It can be seen that the process of 3D printing is not a true printing process. The essence of 3D printing is a manufacturing process. The reason it is named as 3D printing is an image metaphor [12, 13]. The specific process of 3D printing is as follows:

(1) Obtain a 3D Model. The 3D digital model can be obtained in the following two ways. The first method is to draw it with 3D drawing software. In the field of industrial design, three-dimensional drawing design software is widely used to draw renderings of industrial design products. This method is often used in architectural design to draw realistic three-dimensional effects of buildings or interior designs with a high degree of simulation [14, 15]. In these two fields, the use of 3D drawing software to draw 3D models is mostly just to reflect highly realistic design effects. What is needed is only 3D rendering, not to build real 3D objects.

(2) Generate STL File. Once the digital model is obtained by drawing and scanning, the next step is to change the format of the modified model file in the 3D software and convert the model to an STL format file. The surface of the generated STL model file shows a polyhedral structure. When you output the STL file, you need to pay attention to the selection of its parameters. Otherwise, the printed model will also reflect the nonsmooth polyhedral structure, which will affect the print quality of the model.

(3) Model Slice. The slicing technology of the 3D model STL file is one of the core technologies of 3D printing. It is an important bridge connecting the virtual model and the three-dimensional object. If the control of the slicing software is not used, the 3D printer will be completely paralyzed. If the principle of additive modeling is the process of layer-by-layer accumulation, then STL file slicing is the process of cutting the triangular meshed three-dimensional model into several two-dimensional planar digitized paths according to a certain layer thickness [16, 17]; it can be seen that the realization of additive molding mainly relies on model slicing technology. Figure 2 shows the process of generating Gcode files after STL files are sliced.

(4) Debug Printing. After the Gcode file is generated, the slicing software in the computer and the 3D printer can be connected through the data cable for online printing, or the Gcode file can be saved in the memory card and inserted into the card slot of the 3D printer for offline printing [18, 19]. After the preliminary debugging is completed, some test models can be printed to check whether the printing speed and temperature of the nozzle and printing bed of the 3D printer are appropriate, and the model can be printed after the test is completed.

(5) Postprocessing. Most of the printed 3D models have loose and rough support materials. The support materials are added to establish fulcrums for some suspended structures in the 3D model or to expand the contact surface of the printed model to a fixed bottom surface that is too small.

2.2. Vision Sensor Target Detection Algorithm. SVM is a high-dimensional linear classifier. For a given set of feature data points in the feature space, try to ensure that the linear function belongs to the same category [20]. Assuming that an object has x feature data points, the vision sensor target detection algorithm needs to find the feature data points of this object in the feature space to quickly detect the shape and size of the object, and find a vision sensor target detection linear function:

$$f(x) = w^T x + b. \tag{1}$$

Taking a two-dimensional feature space as an example, there are two types of HOG feature points in the two-dimensional feature space, which are represented by circles and crosses. It is necessary to ensure that the two types of sample feature points are linearly separable in the two-dimensional feature space, and a straight line can be used to separate the two types of feature points. This straight line is the linear function $f(x)$. Extending this idea to the high-dimensional feature space, the line is a hyperplane in the high-dimensional feature space; then, the feature point on one side of the hyperplane is $f(x) < 0$, and the feature point on the other side is such that $f(x) > 0$; then, use the hyperplane function which can distinguish the feature points of the two categories, so the essence of the SVM classifier is the problem of finding the optimal solution of the hyperplane [21, 22]. For the case of inseparable linearity in the two-dimensional feature space, it is assumed that the nonlinear classifier $F(x_1, x_2)$ is known and can be expressed as

$$F(x_1, x_2) = ax_1^2 + bx_1x_2 + cx_2^2 + d. \tag{2}$$

Do the transformation as shown in Equation (3):

$$F : R^2 \longrightarrow R^3, F(x_1, x_2) = S\left(x_1^2, x_1x_2, x_2^2\right). \tag{3}$$

Then, it becomes

$$S(z_1, z_2, z_3) = az_1 + bz_2 + cz_3 + d. \tag{4}$$

Based on the above principles, we can quickly detect the feature data points of an object in the low-dimensional feature space and obtain the target detection classification curve of the visual sensor to transform into the feature data points of the high-dimensional feature space, to distinguish the positive and negative sample features of the object [23, 24].

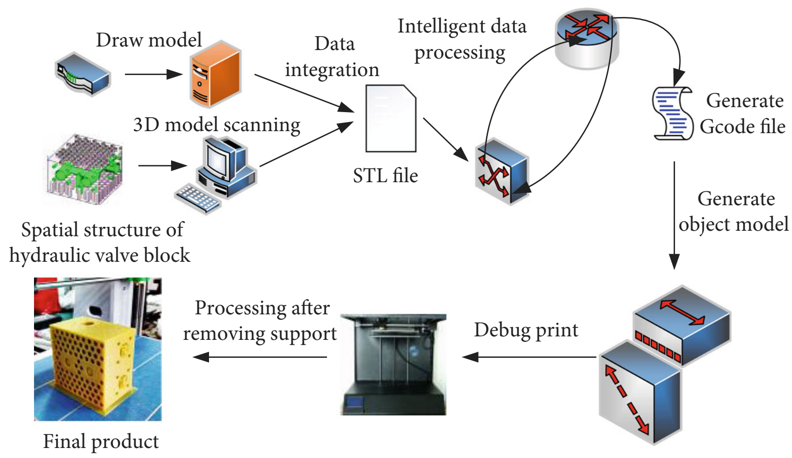


FIGURE 1: 3D printing specific operation flow chart.

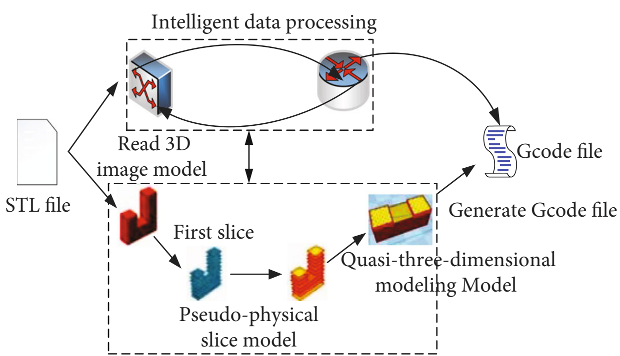


FIGURE 2: Model slicing flowchart.

HOG-SVM has achieved good detection results in the field of pedestrian detection. However, this method does not distinguish the similarity between categories when training the classifier but only judges the target by combining the various regions of the detection category classification, so when detecting similar targets, it is easy to cause false detection.

When using the vision sensor target detection algorithm to detect images, the shape and size of the object in the image are easily affected by the shadow of the object itself and the changes in external lighting, resulting in uneven illumination of the detected image [25, 26]. The square root method is usually used for γ correction. In the case of sufficient illumination, the photoelectron noise is proportional to the square root of the mean value of the illumination, so the square root method γ correction is used to effectively suppress the photoelectron noise signal [27, 28]. In addition, the square root method γ correction has a better effect on rigid targets with relatively fixed contour edge characteristics. The γ correction compression formula is

$$H(x, y) = H(x, y)^{\gamma} = x(\mu_1 - \mu_0)^2 + y(\mu_2 - \mu_0)^2. \quad (5)$$

Among them are the spatial coordinates of the feature points of the object in a certain spatial plane. When the square root method is used for γ correction, the γ value is 0.5. First, the gradient descriptor $[-1,0,1]^{T}$ is used to obtain the gradient component $G_x(x, y)$ in the horizontal direction. In the same way, the gradient component $G_y(x, y)$ in the vertical direction is obtained. Take a certain point $H(x, y)$ in image H as an example; its gradient is

$$\begin{aligned} G_x(x, y) &= H(x+1, y) - H(x-1, y), \\ G_y(x, y) &= H(x, y+1) - H(x, y-1). \end{aligned} \quad (6)$$

In the formula, $G_x(x, y)$ and $G_y(x, y)$, respectively, represent the magnitude of the horizontal gradient and the vertical gradient of the pixel (x, y) in the input image H. Then, the gradient size $G(x, y)$ and the gradient direction $a(x, y)$ at the pixel point (x, y) are

$$\begin{aligned} G(x, y) &= \sqrt{G_x(x, y)^2 + G_y(x, y)^2}, \\ a(x, y) &= \arctan \frac{G_x(x, y)}{G_y(x, y)}. \end{aligned} \quad (7)$$

The gradient size $G(x, y)$ of each pixel is weighted to the $a(x, y)$ direction as a weight. After the pixel gradient is obtained, these gradients need to be encoded to form a vector before they can be processed and recognized by the computer [29].

Feature point extraction is an important stage of feature matching. The ability to extract feature positions that are invariant to operations such as scaling, rotation, illumination, and affine transformation directly affects the matching effect.

2.2.1. Scale Space Extreme Value Detection. Using the vision sensor, the target detection algorithm to detect the scale space of the original image can be obtained by convolving a series of Gaussian filter function $G(x, y, \sigma)$ and image $I(x, y)$ with varying scales:

$$L(x, y, \sigma) = G(x, y, \sigma) * I(x, y). \quad (8)$$

Among them,

$$G(x, y, \sigma) = \frac{1}{2\pi\sigma^2} e^{-\left(x^2+y^2\right)/\left(2\sigma^2\right)}. \tag{9}$$

(x, y) is the space coordinate, and σ is the scale factor. This process is also the process of Gaussian blurring the image. The size of σ determines the degree of blur. The larger the value, the more blurry.

$$\begin{aligned} D(x, y, \sigma) &= (G(x, y, k\sigma) - G(x, y, \sigma)) * I(x, y) \\ &= L(x, y, k\sigma) - L(x, y, \sigma). \end{aligned} \tag{10}$$

This formula was chosen because it is simple and efficient to calculate, and it only needs to make differences with the Gaussian image.

2.2.2. Precisely Locate the Extreme Points. After the candidate scale space feature points are obtained when discovering the object, special methods must be used to obtain the exact position, scale, and principal curvature information of the object [24]. This special method is the Taylor expansion of the scale space function $D(x, y, \sigma)$ at candidate feature point X:

$$D(X) = D + \frac{\partial D^T}{\partial X} X + \frac{1}{2} X^T \frac{\partial^2 D^T}{\partial X^2} X, \tag{11}$$

where $x = (x, y, \sigma)^T$, the offset of the extreme point to the candidate feature point X is $\widehat{X}$, and then $\widehat{X} = (x\wedge, y\wedge, \sigma\wedge)^T$. Take the derivative of $D(X)$, and make it equal to 0 to get the extreme point offset:

$$\widehat{X} = -\frac{\partial^2 D^{-1}}{\partial X^2} \frac{\partial D}{\partial X}. \tag{12}$$

The function value $D(X)$ at the extreme point is used to remove low-contrast feature points and reduce the influence of noise. Substituting Equation (11) into Equation (12) can obtain

$$D(\widehat{X}) = D + \frac{1}{2} \frac{\partial D^T}{\partial X} \widehat{X}. \tag{13}$$

2.2.3. Generate SIFT Features. By counting the gradient information in the neighborhood of key points, a direction can be assigned to each key point. For each image point $I(x, y)$, the gradient amplitude $m(x, y)$ and direction $\theta(x, y)$ can be calculated through the four neighborhoods of the point:

$$\begin{aligned} m(x, y) &= \sqrt{(I(x+1, y) - I(x-1, y))^2 + (I(x, y+1) - I(x, y-1))^2}, \\ \theta(x, y) &= \tan^{-1} \frac{I(x, y+1) - I(x, y-1)}{I(x+1, y) - I(x-1, y)}. \end{aligned} \tag{14}$$

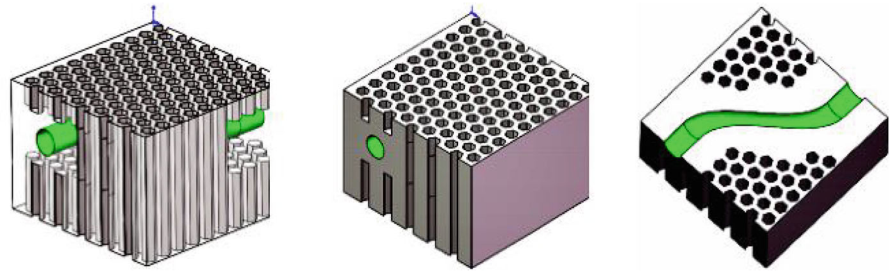
A key point may be assigned multiple directions, which clearly improves the stability of matching [30].

3. Experimental Design of the Innovative Strategy of Vision Sensor 3D Printing in Industrial Design

3.1. Innovative and Free Design of Hydraulic Valve Block Structure. The 3D printing processing method is single and efficient, so the design of parts is more focused on performance, cost, and aesthetics than traditional methods. In the traditional part processing industry, to ensure the mechanical properties of the parts to the greatest extent, a large amount of cold heat treatment and other related work is performed on the parts during the forming process. Without the constraints of the machining process; the structure of mechanical parts can be optimized as much as possible to achieve the win-win goal of saving materials and ensuring performance. The hydraulic valve block is usually subtracted from a whole piece of steel. The material has a high density and a large overall weight. Under the premise of meeting the safety wall thickness, the innovative structure of the hydraulic valve block is simplified, which saves material costs and at the same time can meet the contemporary light-weight green development needs. Refer to the optimization method of high-efficiency load-bearing configuration of composite material structure, and make preliminary structural improvements on valve block parts. The sandwich structure is characterized by high bending rigidity, which can improve the effective utilization of materials and reduce weight. Such a sandwich structure involves two categories of materials and structure. This article mainly draws on its structural characteristics and applies the honeycomb sandwich structure to the lightweight design of the hydraulic valve block.

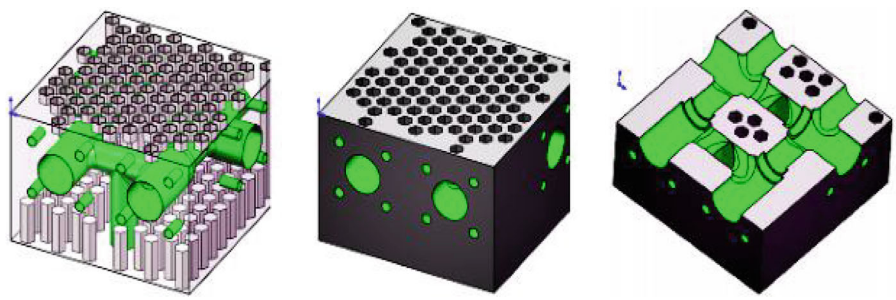
It can be seen from Figure 3 that there is a safe wall thickness around the oil channel, and the rest of the space becomes a honeycomb structure. In this way, the performance of the hydraulic pipeline is not reduced, the materials are saved, and the weight of the entity is reduced. 3D printing can easily realize the processing and manufacturing of this innovative structure, so there is no processing difficulty. Using this principle, a block design is carried out on the universal block of the cartridge valve.

With the above idea of reducing the weight of the hydraulic valve block, the physical structure of the general block of the hydraulic cartridge valve is innovatively designed as shown in Figure 4. This structure simplifies the material based on leaving a hydraulic safe wall thickness,; reduces the weight of the port, thereby the universal block of the cartridge valve; and reduces the weight by at least 30%-40%. In the 3D design of a real hydraulic valve, we first design the simplest channel structure according to the schematic of the hydraulic valve system, extract the channel through which the oil actually passes, and calculate the thickness of its safety wall. Boule driving a channel structure with safety wall thickness and lightweight construction, acquiring the hydraulic valve block model, the hydraulic valve block designed in this way has the best structure and the smallest material.



Schematic diagram of spatial structure | Schematic diagram of overall structure | Planing structure diagram

Figure 3: The lightweight design of hydraulic valve block.



Spatial structure of hydraulic valve block | Overall structure of hydraulic valve block | Planing surface structure of hydraulic valve block

Figure 4: The innovated design of hydraulic cartridge valve generic block structure.

3.2. Innovative and Free Design of Crankshaft Structure. Realize the necessary functions of the crankshaft, and simplify the unnecessary functions in the use of the crankshaft. The undercut, thrust surface, and other structures of the crankshaft are necessary structures for the realization of the machining process, but for the use of the crankshaft, it is unnecessary. These auxiliary structures are not required when the crankshaft is processed by 3D printing, so it can be designed from it being simplified at the beginning, and the specific situation is shown in Figure 5(a). The oil channel is a necessary structure for the crankshaft to realize the lubrication function. The oil passes through the slender and inclined channel to reach the connecting rod journal to lubricate the connecting rod and the bearing bush. Traditional processing is more difficult. 3D printing direct molding simplifies the processing and can also control the oil channel, structure is optimized, the interface is smoothly transitioned, and the stress concentration and oil turbulence are reduced. The specific situation is shown in Figures 5(b) and 5(c).

Based on the 3D printing process and the realization of the necessary functions of the crankshaft, the design of the crankshaft model is shown in Figure 6. The biggest advantage of 3D printing technology for crankshaft processing lies in the simplification of the processing procedures, which saves time and costs and reduces the difficulty of processing.

3.3. Statistical Processing. Statistical analysis was performed with SPSS 13.0 statistical software. The significance test of the difference was performed by one-way analysis of variance, the difference between the two groups was tested by LSD-t, and the statistical situation of the visual sensor 3D printing in the industrial design was performed by the group t-test. $P < 0.05$ is considered significant and statistically significant.

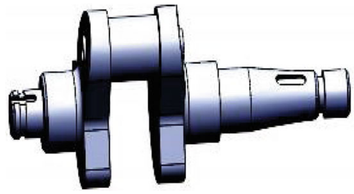
4. Experimental Innovation Strategy of Vision Sensor 3D Printing in Industrial Design

4.1. Printing Process of Universal Block of Hydraulic Cartridge Valve

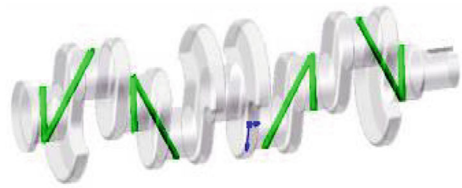
4.1.1. Data Conversion. The first step of 3D printing is to convert the designed SolidWorks 3D graphics files into stl format files. The stl format file uses a triangular grid to represent the file graphics, as shown in Figure 7.

Before slicing, check and repair the model files to avoid unclosed loops and ambiguities. Put the saved stl file into the netfabb software for detection. If there is an incomplete model, an exclamation point warning will appear on the interface. If the model is complete, the slice printing operation can be performed.

4.1.2. Model Slice. Drag the saved 3D model in stl format into the Cura slice software. The opened interface is as shown in the figure below. The left side is the parameter bar with basic settings, advanced settings, and plug-ins, and the right side is the 3D view bar, which can move and zoom the model, rotation, and other operations. In the printing example of the universal block of the cartridge



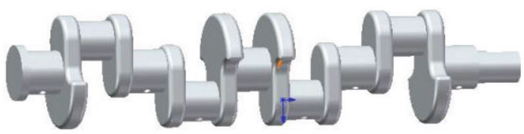
(a) Crank shaft with undercut structure



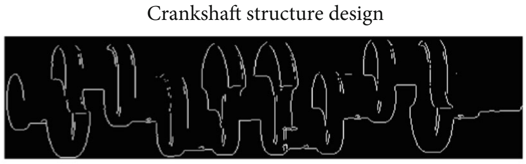
(b) Crank shaft oil channel

(c) Smooth transition

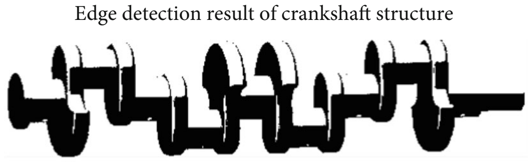
Figure 5: Optimized design of crankshaft and oil duct.



Crankshaft structure design



Edge detection result of crankshaft structure



Crankshaft structure binarization result

Figure 6: The structure design of crankshaft.

valve, the principle of precision requirement is considered: the internal channel structure is more complex and critical. The external plane of the valve block needs to be equipped with hydraulic components, so the process accuracy is higher, so consider the plane perpendicular to the valve block as the processing direction; consider the principle of time-consuming consumables: Cura software will display the printing time-consuming and printing consumables in the upper left corner of the view bar, and the processing direction with less time-consuming consumables should be selected; consider the principle of support removal: the suspended part above the direction processing pipe will generally be an automatically generated support, but because it is an inner cavity structure, you must consider how to remove the support after processing. In this article, the inner channel is connected to the outside but is at a right angle. If you add support here, it will be difficult to remove, so consider making it perpendicular to the work for table processing; there is no need to provide support inside it. In addition, the hexagonal holes provided for material reduction also get better molding conditions in this direction. The molding results in different directions are shown in Figure 8.

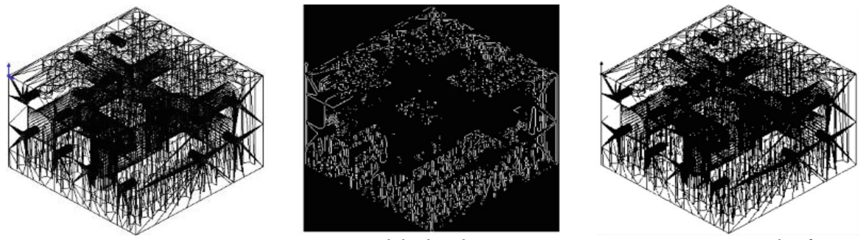
From Table 1, it can be seen that the consumption of consumables in the molding direction 1 is the smallest, but the inner groove is a blind hole, and it is difficult to remove the support after processing. Molding direction 2 consumes a little more time-consuming consumable, but not so much, but the channel support is very good and easily removes molding; direction 3 has no advantages in all respects. After a comprehensive comparison of several molding directions, select molding direction 2 as the machining direction.

4.1.3. Model Printing. Insert the SD card into the 3D printer and start printing. The system automatically applies support to the suspended surface of the tunnel, as shown in Figure 9. The entire printing process runs smoothly. The actual printing time is 5 hours and 10 minutes. After the printing is completed, the excess support is removed, and the printing is over.

4.1.4. Finished Product Display. After removing the support in the pores of the valve block, a general block model of the cartridge valve is obtained. As shown in Figure 10, the model perfectly reflects the designed structure with high-dimensional accuracy and surface quality. The quality of the pores in the honeycomb is very good, and there is no big problem with the size and smoothness of the pores. The designed honeycomb structure also meets the safety wall thickness. Under the premise of this, the weight of the valve block is effectively reduced. The superiority of the innovative design of the hydraulic valve block is verified. To further verify the machinability of the hydraulic valve block with 3D printing technology, metal 3D printing technology should also be used to physically manufacture the valve block, while verifying its feasibility in practical engineering applications.

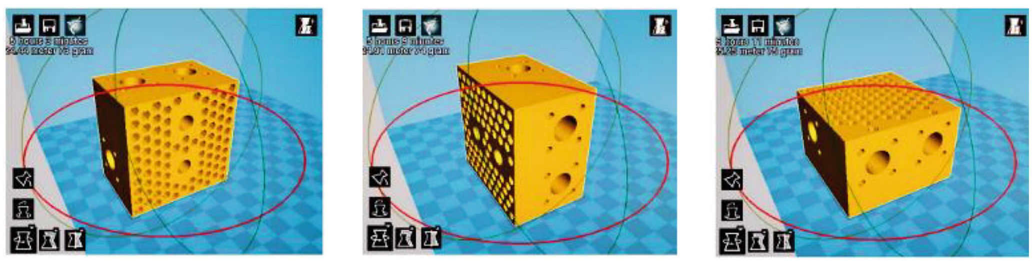
4.2. Printing Process of the Crankshaft Structure

4.2.1. Data Conversion. Save the designed three-dimensional model of the crankshaft in the stl format, and name it



3D model in stl format — 3D model edge detection result in stl format — Binarization result of 3D model in stl format

FIGURE 7: 3D model of stl format.

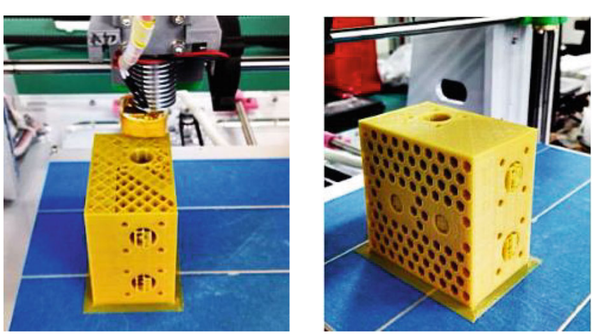


Forming direction 1 — Forming direction 2 — Forming direction 3

FIGURE 8: Forming results in different directions.

TABLE 1: Comparison results of three molding directions.

Forming direction	Time-consuming printing	Printing supplies	Support removal is difficult
1	5 h 3 min	24.44 m	Inner pores are more difficult
2	5 h 10 min	24.91 m	Easier
3	5 h 19 min	25.52 m	Inner pores are more difficult



Supporting the channel by the system — Printing complete

FIGURE 9: Print the result of hydraulic valve block model.

quzhou.stl; that is, use a triangular mesh to represent each surface of the crankshaft, as shown in Figure 11.

Import the model file into netfabb software to check its integrity, and the result obtained is normal. It means that the model has no errors and can be printed.

4.2.2. Model Slice. Unlike laser selective melt molding techniques, shorter three-dimensional dimensions are usually chosen as the molding direction to reduce the molding time. Fused deposition modeling is formed by scanning and spraying material from a nozzle. The size of the cross-sectional area does not affect the printing time. Therefore, the choice of molding direction requires additional considerations. Based on the two principles of minimum material saving and minimum printing time, the product has two molding orientations as shown in Figure 12.

As shown in Table 2, under the same slicing parameters, molding direction 1 saves 10 minutes of time compared to molding direction 2, while molding direction 2 saves 0.56 meters of material compared to 1. The most critical structure of the crankshaft structure is its working structure, the main journal, and the connecting rod journal. Therefore, the accuracy of the shaft is higher than that of other parts. From the step effect, it can be seen that the direction perpendicular to the axis is the processing direction to help improve the molding accuracy of the cylindrical surface; the crankshaft structure has no blind holes that cannot be touched, and most of the support is applied to the outside of the structure, which is easy to remove; in addition, the experience obtained from the comparison of multiple printings shows that the crankshaft printed in the molding direction 2 can have more good surface quality of parts. Therefore, after considering the three elements of forming direction selection, the direction shown in Figure 12 is selected as the machining direction of the crankshaft model.

4.2.3. Model Printing. Insert the SD card into the 3D printer to print the crankshaft. Before printing, the printer is adjusted, the hot bed and the nozzle are preheated, and then,

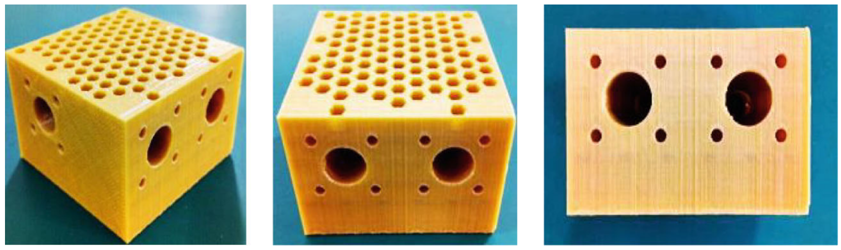


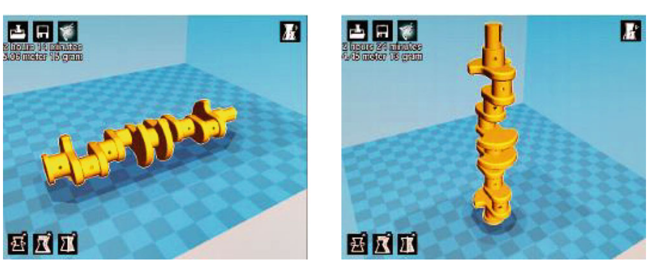
Figure 10: Display of all aspects of the finished hydraulic valve block.

Crankshaft structure in stl format

Edge detection result of
crankshaft structure in stl format

Binarization result of
crankshaft structure in stl format

Figure 11: Crankshaft structure of STL format.



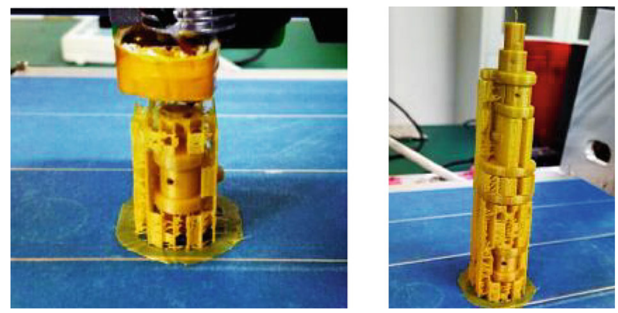
Processing direction 1 Processing direction 2

Figure 12: Selection of two processing directions.

Table 2: Comparison results of two molding directions.

Forming direction	Time-consuming printing	Printing supplies	Support removal is difficult
1	2 h 14 min	5.06 m	Easier
2	2 h 24 min	4.45 m	Easier

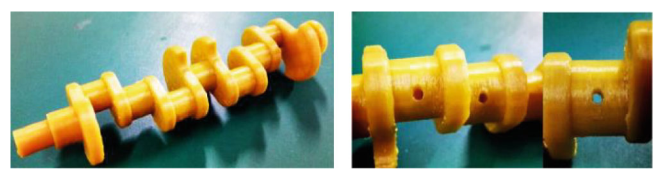
printing starts according to the designed model. During this period, the system automatically adds support and runs smoothly. As shown in Figure 13, the main journal and connecting rod shaft of the crankshaft are well obtained. The



Supporting by the
system automatically

Printing complete

Figure 13: Crankshaft model printing results.



Crankshaft finished
product display

Printed crankshaft
channel structure

Figure 14: All aspects of the finished crankshaft are displayed.

printing effect and printing accuracy and the forming effect of the oil channel are also very good. The actual printing time is 2 hours and 30 minutes. After the model is formed, the part is removed and the support is removed to complete the part forming process.

4.2.4. Finished Product Display. As shown in Figure 14, the molded part is printed after the support is peeled off, and the crankshaft structure is displayed. Judging from the printing results, it meets the expected requirements. Although the crankshaft structure still has shortcomings such as burrs and poor quality of the overhanging surface due to the material and process, the dimensional accuracy of the printing is very high, and the processing quality of the oil passage hole is also very high. Yes, it verifies the machinability of 3D printing of crankshaft structure to a certain extent and proves that the 3D-printed crankshaft has certain structural superiority and processing superiority in the field of engineering manufacturing in the future.

5. Conclusions

With the continuous development of 3D printing technology, printing materials, and related industries, user-centered design will continue to be deepened, and products will become a tool for people's self-awareness, and they can easily participate in the design and production of this design mode. 3D printing technology's interactive relationship in the design and molding process influences and restricts each other and at the same time promotes each other. In the future, 3D printing technology will certainly exert its greater advantages and influence, which is a strategic Chinese manufacturing industry. Based on the related theory of vision sensor 3D printing, this paper studies the application of 3D printing technology in industrial product design and direct manufacturing, proposes a free design method for 3D printing, carries out innovation and free design of mechanical parts structure, and verifies the feasibility of processing. Based on 3D printing, the application of the free design method of mechanical parts is carried out. It is found that the mechanical parts designed by the free design method can indeed improve their performance and have more processing advantages, indicating that 3D printing can be well applied in the field of mechanical design. 3D printing technology is used to realize innovative design result models, the structure of innovative and freely designed machine parts is machinable, and 3D printing has processing advantages in the manufacture of machine parts. I found the disadvantages of this article: the design and 3D printing contained in this article have not been used to test its practicality on real machines. Traditional mechanical design has formed specific standards and systems after years of experience and specific processing methods. Free design methods based on 3D printing should have some impact on industry standards. It is necessary to gradually and deeply study the free design method of mechanical parts and form a system that guides the development of mechanical design in a better direction.

Data Availability

The data underlying the results presented in the study are available within the manuscript.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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