Hindawi
Mobile Information Systems
Volume 2022, Article ID 2272699, 14 pages
https://doi.org/10.1155/2022/2272699

Research Article

DLP-Based 3D Printing for Automated Precision Manufacturing

Weiping Deng,[1] **Deqiao Xie**,[2] **Fuxi Liu**,[1] **Jianfeng Zhao**,[1,3] **Lida Shen**,[1,3] **and Zongjun Tian**[1,3]

[1]*College of Mechanical and Electrical Engineering, Nanjing University of Aeronautics and Astronautics, Nanjing, 210016 Jiangsu, China*
[2]*College of Energy and Powder Engineering, Nanjing University of Aeronautics and Astronautics, Nanjing, 210016 Jiangsu, China*
[3]*National Key Laboratory of Science and Technology on Helicopter Transmission, Nanjing University of Aeronautics and Astronautics, Nanjing, 210016 Jiangsu, China*

Correspondence should be addressed to Weiping Deng; wpdeng@nuaa.edu.cn

Received 4 March 2022; Revised 23 March 2022; Accepted 31 March 2022; Published 4 May 2022

Academic Editor: Chia-Huei Wu

As a new type of rapid prototyping technology, 3D printing technology effectively solves the problems of large errors and waste of resources in traditional manufacturing technology. Compared with other technologies, DLP technology has the following advantages: high reliability, high brightness, rich and gorgeous colors, and is very suitable for portable devices. This article aims to study the application of embedded microprocessor-based DLP3D printing in automated precision manufacturing. This article puts forward the idea of applying DLP3D technology to more automated precision manufacturing. This article introduces the embedded microprocessor, 3D printing technology, and related algorithms in detail. At the same time, this article also conducts experiments on DLP3D printing technology. Through the analysis of samples printed by DLP3D technology, the experimental results show that the material deviation value of DLP3D printing based on embedded microprocessor is generally small, compared with other technology printing the deviation value of the material is also reduced by 15.6%.

1. Introduction

At present, the output value of the casting industry in the manufacturing industry is getting higher and higher in all countries in the world. With the escalating competition in the global smart manufacturing industry, the new pattern will face a major adjustment and change [1]. To speed up the development of the manufacturing industry, we must start with new processes, new materials, and new manufacturing equipment. The precision casting technology has undergone great changes, especially in the aspect of flexible manufacturing, and the efficiency has been greatly improved and improved. In foreign countries, DLP3D printing technology based on embedded microprocessor has developed rapidly and has been recognized by the broad market. There are many disadvantages in the direct manufacturing of high-precision models. In the traditional process of manufacturing components, the cooperation of multiple devices or multiple processes is required. The process is complex, the process is many, the production cycle is long, the manufacturing cost is high, and it is suitable for mass production or standardized production. Compared with traditional technology, 3D printing technology can manufacture parts of various shapes without using other machines, molds, fixtures, and other tools. Therefore, 3D printing technology is also suitable for the production of small batches and individual customization.

Automated high-precision manufacturing, through 3D printing, can quickly manufacture products with complex shapes such as free-form surfaces. Because cutting is not wasted during the processing, it can save the company's raw materials and reduce the waste of resources. 3D printing technology is also possible. Further optimize the design, quickly turn it into a real object, and conduct specific inspections on the correctness of the design, the rationality of the model, the assembly, and the interference, so as to reduce the risk of product development. At the same time, 3D printing technology can quickly manufacture complex parts and components directly from computer-designed drawing data to physical parts without using molds. 3D printing technology has greatly shortened the manufacturing process of complex parts and greatly shortened the product development and manufacturing cycle. At the same time, through 3D printing technology, the utilization rate of materials has been greatly improved. The material is fully utilized in the printing and molding process [2, 3]. After printing, the product can only be used after a simple tracking process, so the material utilization rate reaches 60%, or even more than 90. In other words, 3D printing technology has unparalleled advantages in the field of automated high-precision manufacturing, which can shorten product development cycles, improve material utilization and product performance, and show the prospects and applications of 3D printing technology in the field of automated high-precision manufacturing.

With the continuous advancement of science and technology, people have made relevant researches on the relevant content of 3D printing technology based on embedded microprocessors. On embedded microprocessors, Filipe studied the impact of register file errors on the reliability of modern embedded microprocessors through fault injection and heavy ion experiments in a study [4]. Clark L T adopts many methods in the design to minimize the performance degradation caused by reinforcement and limit the increase of power. A method to resist radiation by designing embedded microprocessor is proposed [5]. Hida I stated in the research on power consumption of embedded microprocessors that his goal is to reduce the power consumption of microprocessors embedded in such devices by using a novel dynamically reconfigurable accelerator [6]. In view of the limitations of traditional recognition, Chen D designed an embedded application system based on iris recognition technology to realize the functions of iris information collection, input, registration, and recognition. The system architecture uses the embedded microprocessor of the advanced RISC machine (ARM) as the core design [7]. In the related research of 3D printing technology, Wang X outlined in a research report the performance and performance of polymer composite 3D printing technology and 3D printed composite parts, and their applications in the fields of biomedicine, electronics, and aerospace engineering, and potential applications [8]. Regarding the research of 3D printing technology in medicine, Jonathan G did research on the application of 3D printing in the field of biological manufacturing, which aimed to review the process of 3D printing technology used in pharmaceuticals, including the parameters to be controlled [9]. Regarding the research of 3D printing technology in building materials, Gosselin C stated that he proposed a new large-scale 3D printing process for cement materials. Structures with complex geometries can be produced without temporary support [10, 11]. Although these researchers have done well in the application research of embedded microprocessors and 3D printing technology in the field of daily life, most of their research did not consider that embedded microprocessors and 3D printing related technologies may be encountered in actual applications. No specific solutions have been proposed for the problems reached.

The innovation of this paper lies in (1) the dlp3d printing technology based on embedded microprocessor is studied, and its application in automatic precision manufacturing is analyzed. (2) Through the research of dlp3d printing based on embedded microprocessor in the field of brake precision manufacturing, we can provide some methods to realize more automatic and higher precision manufacturing by using dlp3d printing technology. (3) Through the research of dlp3d printing technology in automatic precision manufacturing, some possible problems can be found. (4) By improving the problems existing in the research, we can better promote the development of dlp3d printing technology based on embedded microprocessor in the field of automation and high-precision manufacturing.

2. The Method of DLP3D Printing of Embedded Microprocessor in Automated Precision Manufacturing

2.1. Embedded Microprocessor

2.1.1. The Basic Concept of Embedded Microprocessor. The embedded microprocessor is developed from the CPU of a general-purpose computer. A 32-bit or higher processor is its characteristic, with high performance, and the corresponding price will rise. Compared with industrial control computers, embedded microprocessors have the advantages of small size, light weight, low cost, and high reliability [12]. Embedded systems are based on application programs and computer technology. It adapts to software and hardware, adapts to function, reliability, cost and capacity. This is a special purpose computer system that can be adapted to applications related to power consumption strictly required [13]. It can realize the control, monitoring, management, and other functions of other equipment. This is user-oriented, product-oriented, and application-oriented, combining advanced computer technology, semiconductor technology, electronic technology, and specific applications in different industries. Embedded systems have small kernels, streamlined systems, and powerful specific functions, and require special development tools and environments for development. Its main feature is its purpose or relevance [14]. In other words, the development and design of each embedded system have special application possibilities and specific functions. This is also the main difference between embedded systems and general computer systems.

Embedded systems usually consist of four parts: embedded processors, peripheral hardware devices, embedded operating systems, and user application software. The core part is the embedded processor. The embedded processor architecture has shifted from CISC (complex instruction set) to RISC (reduced instruction set) and compact RISC, and the number of bits has gradually developed from 4, 8, 16, and 32 bits to 64 bits. Embedded processors generally

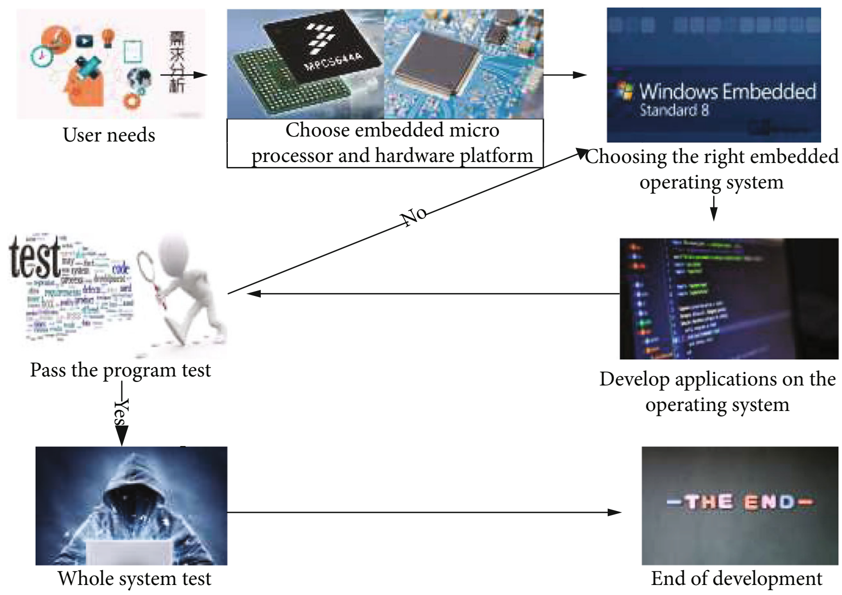

Figure 1: Embedded system development process.

used include low-end embedded microcontrollers, mid-end to high-end embedded microcontrollers, embedded DSP processors, and highly integrated embedded system chips for classification [15]. There are more than 1,000 processors and more than 30 series in the world. Different processors have different functions and advantages, but for embedded system applications, low cost, low power, and high performance are special requirements. At present, the main types of embedded processors are PowerPC, MC 6800, MIPS, and ARM/Strong ARM series.

2.1.2. Embedded System. Embedded system is an application-centric dedicated computer system based on the latest computer technology. User requirements (function, reliability, cost, volume, power consumption, environment, etc.) are based on needs and can be flexibly adjusted through software and hardware modules. In the embedded system development process, the hardware platform of each processor is universal, fixed, and mature, so the possibility of hardware system errors during the development process is very low. However, different hardware systems have different operating system requirements. If the memory requirements are not high, you can choose an operating system with high compatibility. When the requirements of the operating system are high, a more rational kernel is needed [16, 17]. At the same time, the embedded system protects a lot of complex information of the basic hardware, and developers can complete most of the work through the API functions provided by the operating system. As a result, the development process is greatly simplified and the stability of the system is improved [18]. Figure 1 shows the basic flow chart of embedded system development.

2.2. 3D Printing Technology. 3D printing technology, also known as additive manufacturing technology or rapid prototyping technology, is a manufacturing technology for rapidly manufacturing solid devices based on digital signals, using powder or liquid metal, plastic, and other viscous materials, and stacking layer by layer by spraying, extrusion, melting, sintering, light curing, and other methods. 3D printing technology is also known as layered modeling technology. 3D printing is to generate three-dimensional objects by stacking and stacking layers. At the same time, 3D printing technology includes computer vision, computer graphics, graphic recognition and intelligent systems, photoelectric integration, automatic control of complex systems and engineering materials, and data mining, and is a technology that includes mechanical learning and application of digital modeling technology [19, 20]. In recent years, 3D printing technology has been widely used in aerospace, aviation, automobile manufacturing, medicine and health, and other fields.

3D printing technology is based on a three-dimensional model, using adhesives to build objects through the printing of various layers. The most intuitive embodiment of the 3D printing principle is the function of its design, editing, and control software. The three-dimensional digital model is discretized on a series of two-dimensional cut thin surfaces, and the filling path of the molding is as follows: reasonably plan, process with a molding system, accumulate materials in layers, and eventually attach to 3D objects [21]. The layering process is equivalent to advanced mathematical differential operations, and the cumulative manufacturing process of each layer is equivalent to advanced mathematical integration operations [22]. Figure 2 illustrates the 3D printing process.

The process flow is shown in Figure 2: establish the three-dimensional digital model of the part in the computer software system, turn the triangular mesh of the model into STL standard file, then use the professional slicing software to carry out layered processing on the STL model, load the obtained scanning path file into the 3D printing equipment to generate the model, and finally carry out post-processing on the model.

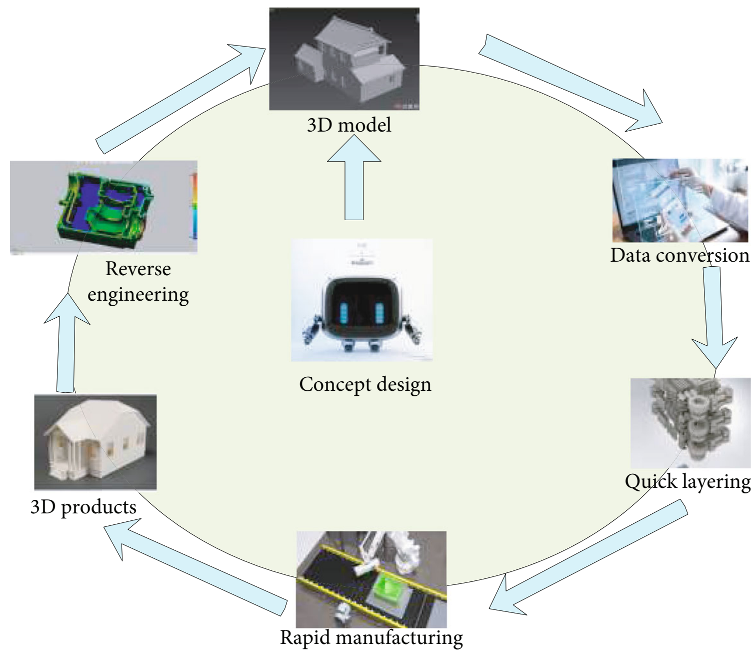

Figure 2: 3D printing process.

2.2.1. Types of 3D Printing Technology. According to different materials, 3D printing technology can be divided into metal printing and non-metal printing; according to different molding processes, 3D printing technology can be divided into selective laser sintering (SLS), selective laser melting (SLM) and electron beam melting (EBM), fused deposition modeling (FDM), stereolithography (SLA), and layered object manufacturing (LOM).

2.2.2. DLP3D Printing. DLP is digital light processing technology, that is, this technology needs to digitally process the image signal first, and then project the light. DLP 3D printing is a type of molding technology, surface exposure molding technology. DLP 3D printing technology has many similarities with stereolithography three-dimensional (SLA 3D) printing molding technology. DLP 3D printing technology uses a high-resolution digital light processor (DLP) to harden the liquid photopolymer. After the liquid polymer is solidified in layers, it is repeated until the final model is completed [23]. DLP 3D printing molding technology generally uses photosensitive resin as a 3D printing material. DLP has unique advantages compared with other types of 3D printing technology. It is a technology to complete the visual digital information display based on the digital micromirror device DMD (digital micromirror device) developed by Texas Instruments (TI). Specifically, DLP projection technology uses the digital micromirror chip (DMD) as the main key processing element to realize the digital optical processing process. First of all, the optical machine fixation reduces the number of moving parts, and the deviation caused by vibration is small, and products with higher precision and better stability can be manufactured [24]. Second, more detailed parts can be manufactured. Taking jewelry as an example, mass-produced printing rings can reduce manufacturing costs to a certain extent, and may lose wax casting directly after printing. The manufacturing cycle of the product is shorter than the manufacturing cycle of the product. The conventional process time has more than doubled. Affected by factors such as low price, low printing cost, and easy operation, 3D printers based on DLP forming technology are increasingly accepted by consumers. At present, DLP 3D printing technology has many fields such as medical treatment, construction, transportation, aerospace, archaeology, education, industrial manufacturing, gems, and toys [25, 26]. But things always have two sides. While people enjoy the convenience brought by 3D printing technology, we must face up to the problems of 3D printing model accuracy and reliability technology with a cautious attitude, and strive to explore how to make the technology have better services. Figure 3 is the principle and finished product diagram of DLP 3D laser forming technology.

2.2.3. SLA Light-Curing Three-Dimensional Molding. The SLA process can be said to be the earliest 3D printing process in the world, and at the same time, it is also the world's first printer to use process. The principle is to focus the laser with specific wavelength and intensity on the surface of the light-curing material, make it solidify from point to line and from line to surface, complete the drawing of a horizontal section, and then move the height of one layer in the vertical direction, continue to solidify the next layer, and stack layer by layer to form a three-dimensional real object. SLA technology mainly includes operations such as the initial construction of a three-dimensional model, the processing of sample data, the curing of photosensitive resin materials, and the post-processing of samples. And this operation uses ultraviolet laser; most of the raw materials are photosensitive resin [27]. The laser head is focused on the surface of the light-hardening material, and under the control of the computer, e movement of the slide, the workbench only reduces

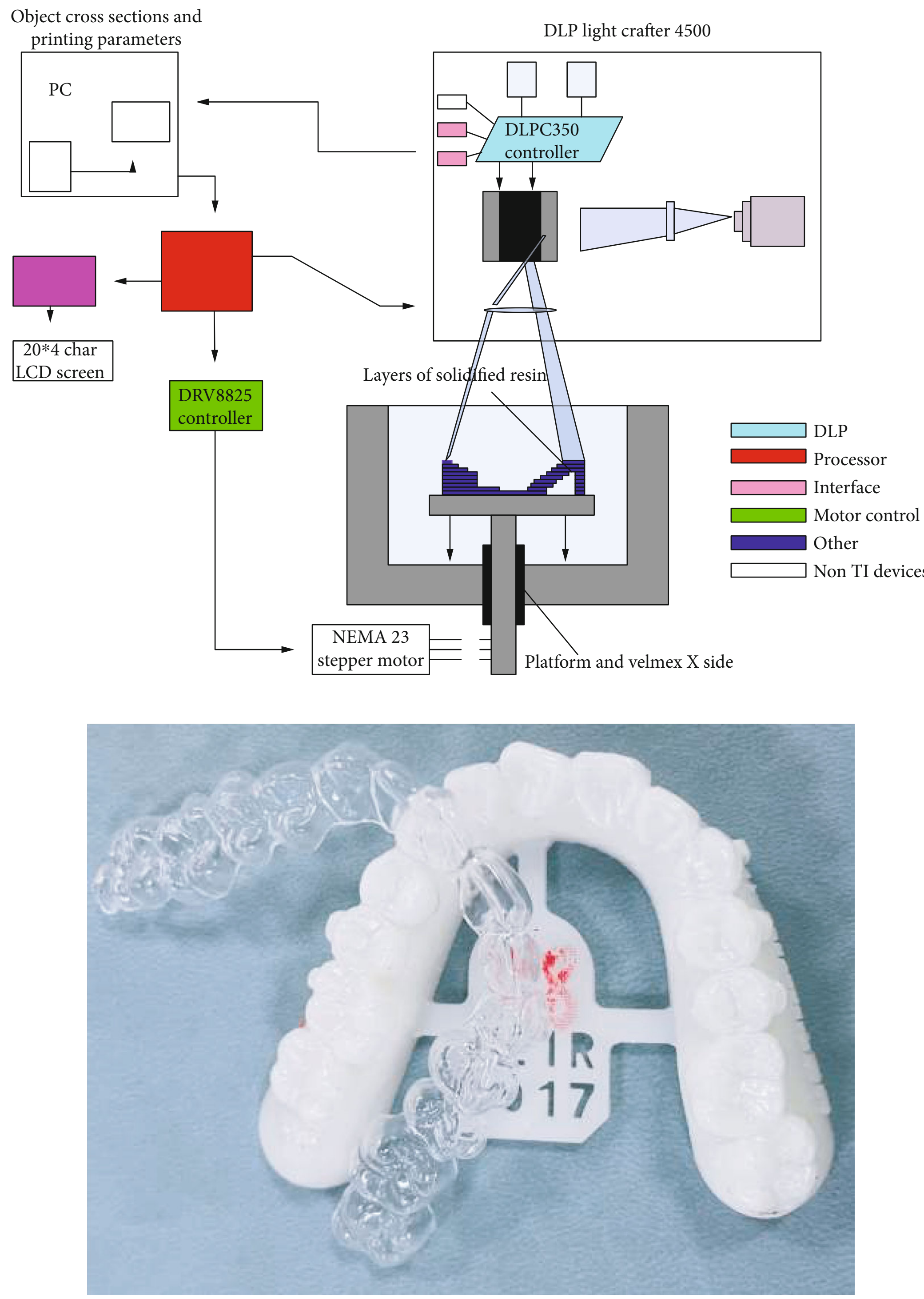

Figure 3: DLP3D laser forming technology.

the thickness of the layer, and the other layer of liquid resin is covered on the hardened layer, and then this layer is covered. Before the establishment of a complete three-dimensional entity, these operations will continue to be repeated [28, 29]. Figure 4 shows the SLA light-curing three-dimensional molding technology and its finished products.

2.2.4. SLS Selective Laser Sintering. SLS technology mainly uses infrared lasers for product production. The raw materials of its products are generally plastic, wax, ceramics, metal powder, etc. SLS uses the principle of sintering powder materials under laser, computer control, and layer-by-layer sintering to make products [30]. First, unfold the powder layer, wipe it with a scraper, and then heat the material to

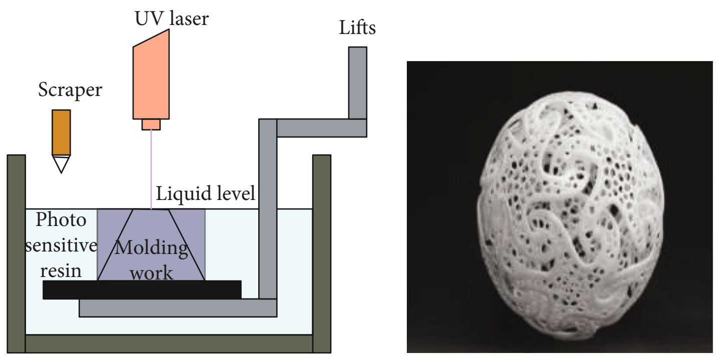

Figure 4: SLA light-curing three-dimensional molding technology.

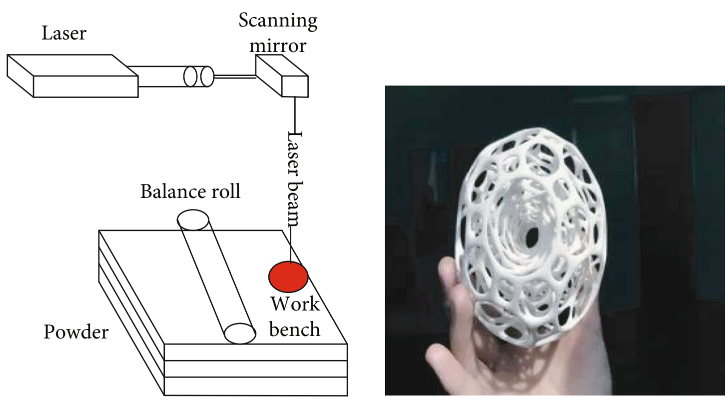

Figure 5: SLS selective laser sintering technology.

near the melting point of the material, and then use an infrared laser to selectively scan and sinter the layer so that the temperature of the powder reaches its melting point and melts. After forming a layer, lower the table at the height of the layer thickness, the powder is diffused and sintered until the three-dimensional product is formed [31, 32]. Figure 5 shows the principle of SLA selective laser sintering technology and its finished product.

2.2.5. FDM Fused Deposition Molding. FDM technology mainly includes three-dimensional modeling, data processing, heating materials, melting molding, and post-processing. The technical principle is to heat the filament-like material (paraffin, metal, plastic, low melting point alloy wire) and dissolve it from the nozzle. There is a thin nozzle at one end of the nozzle to squeeze the material with a certain pressure. Under the control of the computer, the molten material will be spread on the workbench and will form a product layer after cooling. The nozzle rises to the height of the layer thickness and continues to melt and deposit [33]. Open before finishing. Finally, take out the product, remove the support, and perform post-processing. To put it simply and clearly, FDM technology is as simple as spinning and squeezing toothpaste, and the price is relatively cheap. Because most of the technical systems are desktop level 3D printing equipment, and the raw materials used are polylactic acid (PLA), so the equipment cost and material price are relatively low, and there is no use of vulnerable parts such as laser galvanometer, so the operation and maintenance cost of this technology is low; almost all desktop printers on the market use this program, and it is the manufacturer's favorite [34, 35]. At the same time, this technology also has the advantages of simple operation, fast molding speed, good material properties, and simple post-processing. Therefore, FDM is also widely used in orthopedics, maxillofacial surgery, and other related medical fields. Figure 6 shows the principle of FDM fused deposition molding technology and its finished product diagram.

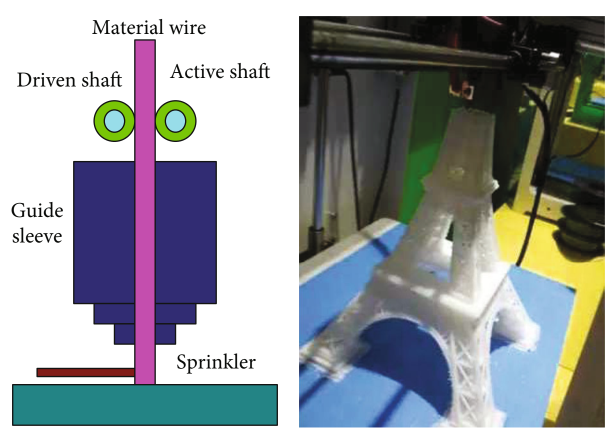

Figure 6: FDM fused deposition molding.

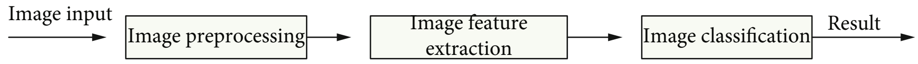

Figure 7: Image processing flowchart.

2.2.6. Related Algorithms in DLP3D Technology

(1) Hierarchical Algorithm. When introducing the layering algorithm, it is necessary to understand the related content of the continuity of the triangle itself between the triangle faces in the DLP file.

In terms of geometry, the triangle itself is a relatively special figure, with the characteristics of regional continuity, scan line continuity, and edge continuity [36]. The triangle itself is a single convex area of the plane, and there is no need to prove the continuity of the area. The continuity of the scan line means that when the scan line intersects the triangle patch, the intersection line must be formed by the intersection of the scan line and the line connecting the two sides of the triangle [37, 38]. The continuity of the side can be expressed by the progressive formula of the line segment intercepted by the two sub-levels intersecting the triangle. For example, the vertex coordinates of the triangle are Q1 (a1, b1, c1), Q2 (a2, b2, c2), and Q3 (a3, b3, c3). The intersection of the current sub-level height $G = c[i]$ and the coordinate Q1Q2 side is $(a[i], b[i])$. After adding the layer thickness to the sub layer, the height of the current layer is $G = c\,[i+1]$, and the obtained cross coordinate is $(a[i+1, b[i+1])$.

The interval Δ between the layers is determined as P, and the coordinates of the intersection points of similar layers can be obtained by the delamination algorithm based on the triangle continuity. If they are on the same side, there is a gradual formula.

$$\begin{cases} A_a = (a_1 - a_2)/(c_1 - c_2) \\ A_b = (b_1 - b_2)/(c_1 - c_2) \end{cases}, \tag{1}$$

where A_a and A_b are proportional coefficients, then

$$\begin{aligned} a[i] &= a_1 + A_a(c_1 - c[i]), \\ b[i] &= b_1 + A_b(c_1 - c[i]), \\ a[i+1] &= a_1 + A_a(c_1 - c[i+1]), \\ b[i+1] &= b_1 + A_b(c_1 - c[i+1]). \end{aligned} \tag{2}$$

From the above formula

$$\begin{aligned} a[i+1] &= a[i] + \Delta a, \Delta a = (a_1 - a_2)\Delta c/(c_1 - c_2), \\ b[i+1] &= b[i] + \Delta b, \Delta b = (b_1 - b_2)\Delta c/(c_1 - c_2). \end{aligned} \tag{3}$$

Both Δa and Δ are constants determined by Δc. When one side of the triangle crosses the T slice, the coordinates of the T cross only need to be multiplied and divided twice, and 2T needs to be added. All cross-node problems will be resolved.

(2) Equidistant Offset Algorithm. The image processing process mainly includes image input, feature analysis, image preprocessing, feature extraction, and result output. There are five steps. Figure 7 is the image processing flow chart.

This section mainly introduces several digital image processing methods, such as Sobel edge detection and Gaussian smoothing filter.

(1) Sobel edge detection

The edge of the image is an important part of the image information that contains internal information such as outline, direction, and sudden changes. Image segmentation, classification, and pattern recognition are the basic operations that often use edge detection. When an image acquisition device is used to acquire an image, the acquired image contains a lot of high-frequency noise caused by factors such as ambient light, thermal noise of image elements, and electromagnetic interference. Therefore, in order to improve the accuracy of classification or recognition, the original image must be processed before classification or recognition. Using edge detection algorithms with excellent performance can effectively remove noise and improve the accuracy and stability of post-processing. The Sobel operator uses a convolution template to perform a convolution operation on the image of the processing object to achieve the effect of edge detection. The two $3*3$ convolution templates used by this operator are shown below.

$$\begin{aligned} S_q &= \begin{pmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -3 & 0 & 3 \end{pmatrix}, \\ S_o &= \begin{pmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{pmatrix}. \end{aligned} \tag{4}$$

In the image to be processed, the central pixel value is recorded as $G(a, b)$, and the function matrix around $3*3$ is shown below.

$$\begin{pmatrix} G(a-1, b-1) & G(a-1, b) & G(a-1, y+1) \\ G(a, b-1) & G(a, b) & G(a, b+1) \\ G(a+1, b-1) & G(a+1, b) & G(a+1, b+1) \end{pmatrix}. \tag{5}$$

Use the two convolution templates of the Sobel operator to calculate the dominant function near the center pixel $3*3$ in the horizontal and vertical directions, calculated as follows.

$$S_q = \frac{\partial G}{\partial a} = [G(a-1,b+1) + 2G(a,b+1) + G(a-1,b-1) + G(a+1,b+1)] - [G(a-1,b-1) + 2G(a,b-1) + G(a+1,b-1)],$$

$$S_o = \frac{\partial G}{\partial b} = [G(a+1,b-1) + 2G(a+1,b) + G(a+1,b+1)] - [G(a-1,b-1) + 2G(a-1,b) + G(a-1,b+1)]. \quad (6)$$

According to the principle of absolute value addition, the approximate gradient value of the center pixel can be obtained from the first derivative in the horizontal and vertical directions, calculated as follows.

$$F(a,b) = \sqrt{F_a^2 + F_b^2} \approx |F_a| + |F_b|. \quad (7)$$

The Sobel operator is widely used in digital image processing through its obvious effects and simple calculations.

(2) Expansion and corrosion

As the two functional units of digital image morphology processing, it can combine expansion and erosion to form an open operation [39]. Through advanced functions such as closed-circuit calculation, it can further form digital image morphology processing algorithms such as fill-in, sparse, and coarse. The formulas for the expansion operation and the corrosion operation are as follows.

$$M \oplus N = \max_{(x,y)\in N} \left(M_{m+x,n+y}\right), \quad M\Theta N = \min_{(x,y)\in N} \left(M_{m+x,n+y}\right). \quad (8)$$

It can be seen from the above formula that the effect of expansion is to strengthen the area of bright colors, and the effect of corrosion is to strengthen the range of dark colors. For the same image, the order of enlargement and erosion and the number of calculations are different, and different calculation results can be obtained.

(3) Gaussian smoothing filter

Gaussian blur is also called Gaussian smoothing. It is a very effective low-pass filter and is widely and effectively used in the field of digital image processing. The two-dimensional Gaussian smoothing filter is one of the frequently used operations in digital image processing, and its formula is as follows.

$$T(a,b) = \frac{1}{2\pi\alpha^2} p^{-\left(a^2+b^2\right)/2\alpha^2}. \quad (9)$$

Among them, α is the standard deviation, a and b are Cartesian coordinates, and the size of the standard deviation determines the smoothness of the image processing result. In order to improve the calculation performance, the filter parameters are usually calculated in advance. The generally used 5∗5 integer template is as follows.

$$\frac{1}{273} * \left(\begin{array}{c|cccc} 1 & 4 & 7 & 4 & 1 \\ 4 & 16 & 26 & 16 & 4 \\ 7 & 26 & 41 & 26 & 7 \\ 4 & 16 & 26 & 16 & 4 \\ 1 & 4 & 7 & 4 & 1 \end{array}\right). \quad (10)$$

(3) Contour Offset Algorithm. The offset of the contour is actually the parallel offset of the inner and outer contours of the model along different directions. The key question is how to realize the offset of the inner and outer contours to generate scan lines, so that the 3D printer can be manufactured quickly. In 3D printing, because the contour of each layer of the model is obtained by intersecting the plane with the model, that is, the contour of each layer is composed of multiple line segments [40]. Therefore, two situations occur when the contour is offset, self-intersection, and breakpoint. After the offset, the limits are not connected together. This situation is caused by the unevenness of the multi-line segments.

For the judgment of the unevenness of the polygon, the outer contour is selected as the counterclockwise direction and defined as the positive direction, and then the unevenness of the two adjacent lines is judged. Take any two vectors $\overrightarrow{t_i}$ and $\overrightarrow{t_{i+1}}$ as an example. Assuming that the vectors $\overrightarrow{t_i}$ and $\overrightarrow{t_{i+1}}$ are two adjacent vectors and connected in the positive direction, this paper uses the following formula to judge the unevenness of the connection based on the cross product of the two quantities:

$$\overrightarrow{t_i} * \overrightarrow{t_{i+1}} = \begin{vmatrix} m_i & n_i \\ m_{i+1} & n_{i+1} \end{vmatrix} = m_i * n_{i+1} - m_{i+1} * n_i. \quad (11)$$

The geometric meaning of the cross product, when the outer contour is positive in the counterclockwise direction, if $\overrightarrow{t_i} * \overrightarrow{t_{i+1}} > 0$, the connection is a convex vertex; otherwise, it is a concave vertex. Because self-intersection and breakpoints are generated because of the offset of the line segment, the straight line offset method used in this article is an algorithm to find the coordinates of the second point after the offset is based on the three known points. The line segment M1M2 is shown in Figure 8.

Suppose M_5 (x_n, y_n), M_8 (x_m, y_m), and put the coordinates into the following formula:

$$\begin{cases} \overrightarrow{M_1M_2} * \overrightarrow{M_1M_5} = 0 \\ |M_1M_5| = D \end{cases}, \quad \begin{cases} y = (x_2 - x_1)(x_n - x_1) + (y_2 - y_1)(y_n - y_1) = 0 \\ (x_n - x_1)^2 + (y_n - y_1)^2 = D^2 \end{cases}. \quad (12)$$

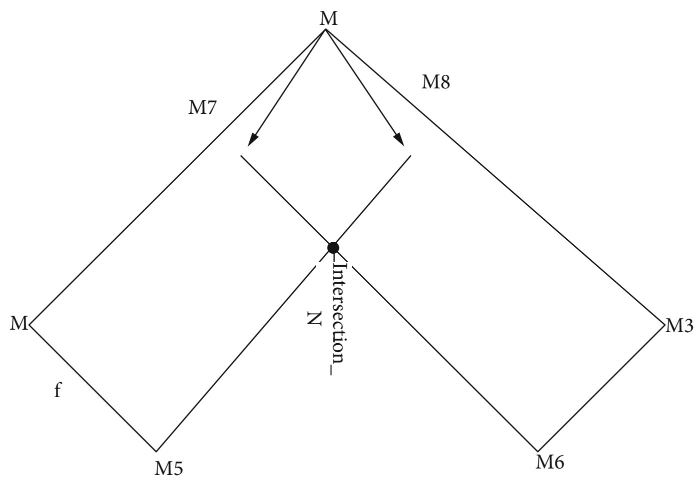

Figure 8: Line segment after offset.

Regardless of self-intersection or breakpoint, the intersection of the two line segments after offset can be obtained by calculating the intersection of the two line segments after offset. The straight line where the line segments M_5M_8 and M_6M_7 are can be obtained as:

$$\begin{cases} y = \dfrac{(y_m - y_n)}{(x_m - x_n)} * x + \dfrac{(x_m y_n - x_n y_m)}{(x_m - x_n)} \\ y = \dfrac{(y_{m+1} - y_m)}{(x_{m+1} - x_m)} * x + \dfrac{(x_{m+1} y_m - x_m y_{m+1})}{(x_{m+1} - x_m)} \end{cases}. \quad (13)$$

In this way, the cheap intersection coordinates can be obtained, and the coordinates of each intersection can be obtained in turn according to the contour, and then connected to obtain the offset contour.

2.3. Precision Manufacturing. Precision manufacturing mainly includes precision and ultra-precision processing technology and manufacturing automation. The former pursues the boundaries of processing accuracy and surface quality, and the latter includes the automation of product design, manufacturing, and management. It is not only a quick response to market demand, but also an important means to increase productivity and improve working conditions, as well as an effective means to ensure product quality. These two are closely related. Many precision and ultra-precision machining rely on automation technology. To achieve the desired goal, many manufacturing automations rely on precision machining functions. Realize it correctly and surely. No matter which one plays an overall and decisive role, it is the backbone of advanced manufacturing technology. In the domestic automation and precision industry manufacturing, aerospace companies use the most in automation and precision manufacturing, and their requirements are more stringent.

3. Application Experiment of DLP3D Printing Based on Embedded Microprocessor on Automated Precision Manufacturing

3.1. Manufacturing and Processing of DLP3D Printing Patterns. This experiment printed circular gears. There are 3 steps to print the shape of a circular gear. Preheat first. The printed sample needs to be melted at high temperature. In order to improve the sintering quality and efficiency, the 3D printing device must reach a certain temperature before the formal printing. Therefore, the 3D printing device needs to be warmed up in advance. Next, enter the project data. After warming up, input the circular gear-shaped data file into the computer to adjust the printing ratio and configuration position. After setting all the parameters, the 3D printing device will automatically calculate the amount of printed matter and the required printing time. Finally, the 3D printer operates according to the parameters of the system process and prints the sintered deposits layer by layer until the entire printing process is completed.

3.2. Post-Processing of DLP3D Printing Appearance. The wheel hub pattern taken out from the 3D printing equipment is wrapped in paraffin, and the paraffin needs to be cleaned to expose the parts. Some molded parts need to be post-cured to repair loopholes and defects. If the precision of the molded parts is higher, the surface of the molded part needs to be polished and polished. These processes are collectively referred to as post-treatment. Part cleaning refers to the process of peeling the supports and attachments on the printed part from the part to expose the true shape of the printed part. The cleaning process of the parts is a meticulous and complicated work. If the operation is improper, the parts will be deformed, which will affect the quality of the parts. Table 1 is the parameter table of commonly used ultrasonic cleaning equipment.

Table 1: Commonly used ultrasonic cleaning machine parameters.

Ultrasonic frequency	42000HZ	Voltage frequency	220-240 V 50-60 Hz
Ultrasonic power	70 W	Heating power	50 W
Capacity	3 L	Time control	2-30 minutes adjustable

Table 2: Distribution of deviation values.

>=Min	<Max	#point	%
-0.2000	-0.1667	190	0.3284
-0.1667	-0.1333	649	1.1218
-0.1333	-0.1000	1671	2.8883
-0.1000	-0.0667	2903	5.0177
-0.0667	-0.0333	5109	8.8307
-0.0333	0.0000	9788	16.9182
0.0000	0.0333	10955	18.9353
0.0333	0.0667	9165	15.8413
0.0667	0.1000	7373	12.7439
0.1000	0.1333	5408	9.3475
0.1333	0.1667	2611	4.5130
0.1667	0.2000	942	1.6282

Table 3: Standard deviation value distribution table.

Distribution (+/-)	#point	%
-6∗standard deviation	10	0.0173
-5∗standard deviation	9	0.0156
-4∗standard deviation	77	0.1331
-3∗standard deviation	949	1.6403
-2∗standard deviation	6527	11.2817
-1∗standard deviation	22559	38.9923
1∗standard deviation	19611	33.8968
2∗standard deviation	6923	11.9661
3∗standard deviation	861	1.4882
4∗standard deviation	191	0.3301
5∗standard deviation	89	0.1538
6∗standard deviation	49	0.0847

3.3. DLP3D Printing Appearance Inspection. In this experiment, an optical CMM3D scanner was used to scan the shape of the tooth model, and the Germanic Control software was used to compare the scanned image with the original image file to obtain the test data, and then use the three-coordinate measuring instrument to compare the shape and position tolerances of the wheel shape. Items are measured.

The three-dimensional overall measurement results are shown in Table 2 and Table 3, respectively, the deviation value distribution table and the standard deviation value distribution table.

The measurement and results of points taken on the three-dimensional surface are shown in Table 4:

3.4. Application of DLP3D Printing in Automated Precision Manufacturing. As one of the high-end printing technologies, DLP 3D printing technology has attracted the attention of various companies. At the same time, companies are competing with each other in order to seize the market. DLP3S printing technology has gradually developed and developed, and industrial and desktop products have begun to appear. The molding rate and molding accuracy of 3D printing have been greatly improved. Based on its core technology DMD chip, DLP has developed from the initial projector to the 3D printing field, and realized the rubber processing of photosensitive resin, which has attracted the attention of many companies and manufacturers. According to recent overseas research, 3D printing time has been shortened by dozens of times, which really opened the door to the development of DLP 3D printing technology. It is worth mentioning that the application of DLP 3D printing has gradually transitioned from prototype to direct manufacturing. According to the statistics of the world's DLP 3D technology service providers and DLP 3D system manufacturers, the proportion of direct manufacturing of high-end precision parts printed by DLP 3D in operating profits has increased year by year. Table 5 shows the application and development of automated high-end precision manufacturing DLP 3D technology in recent years.

Table 4: Numerical table of the deviation distribution of the selected points.

Distribution (+/-)	#point	%
-7∗standard deviation	0	0
-3∗standard deviation	361	26.2
-1∗standard deviation	256	20.3
1∗standard deviation	459	36.8
3∗standard deviation	36	5.6
7∗standard deviation	0	0

Table 5: DLP 3D technology development.

	Parts	Overall equipment	Proportion of production value
2015	7%	12.2%	8.1%
2016	9.8%	13.2%	12.5%
2017	12.6%	15.7%	16.8%
2018	20.8%	16.9%	25.3%

4. Application Analysis of DLP3D Printing Based on Embedded Microprocessor on Automated Precision Manufacturing

4.1. Inspection Results of DLP3D Printing Patterns. Through the experiments in this article, three-dimensional inspections have been carried out on the patterns printed by DLP3D printing technology. According to the test results,

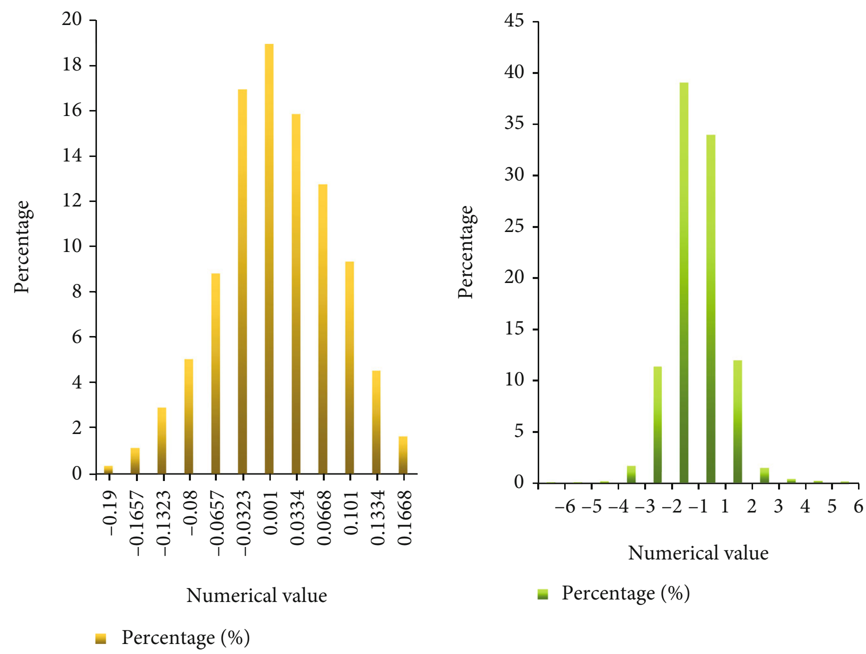

Figure 9: Three-dimensional data statistics.

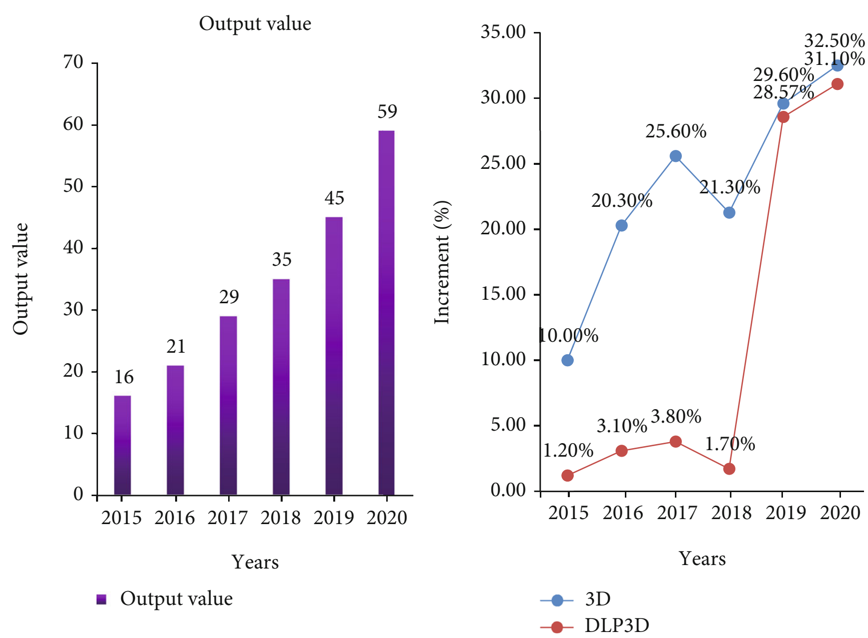

Figure 10: Development and changes of 3D printing and related technologies in recent years.

the tooth pattern data statistics under DLP3D printing technology can be obtained, as shown in Figure 9.

It can be seen from Figure 9 that the deviation of the three-dimensional overall is between -0.0667 and 0.0667, which accounts for the largest proportion, with a total proportion of more than 60%. From the point of view of the numerical deviation of the points on the three-dimensional surface, the deviation value between -2 and 2 accounts for the largest proportion, reaching more than 75%. Generally speaking, the deviation of three-dimensional numerical measurement results is much smaller than that of traditional construction methods.

4.2. Application Analysis of DLP3D Printing in Automated Precision Manufacturing. According to the investigation and research on DLP3D printing technology, we have obtained the output value growth of 3D printing technology in recent years and the global annual output value of DLP3D printing technology in recent years (100 million U.S. dollars), as shown in Figure 10.

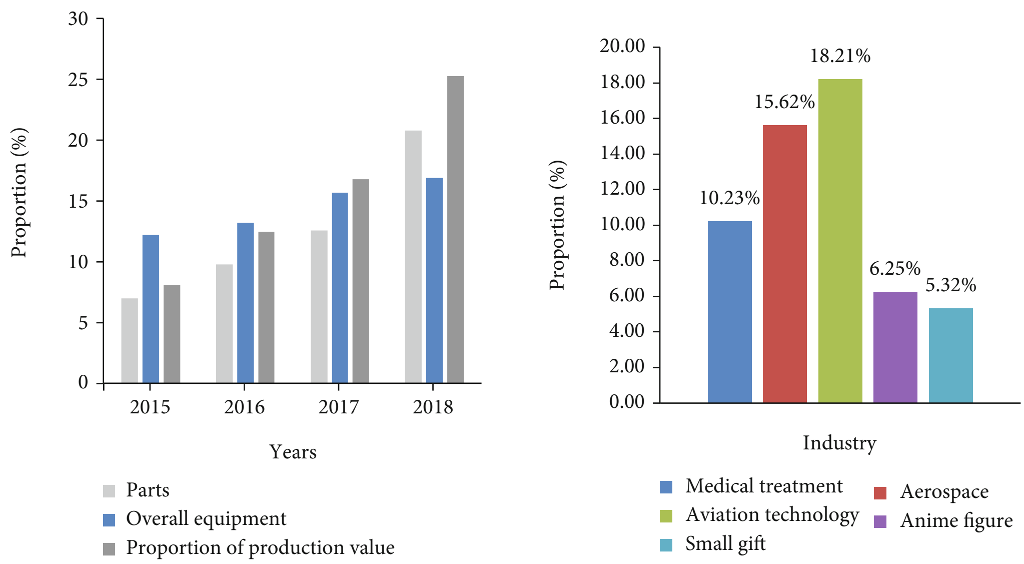

Figure 11: The recent development of DLP3D printing technology.

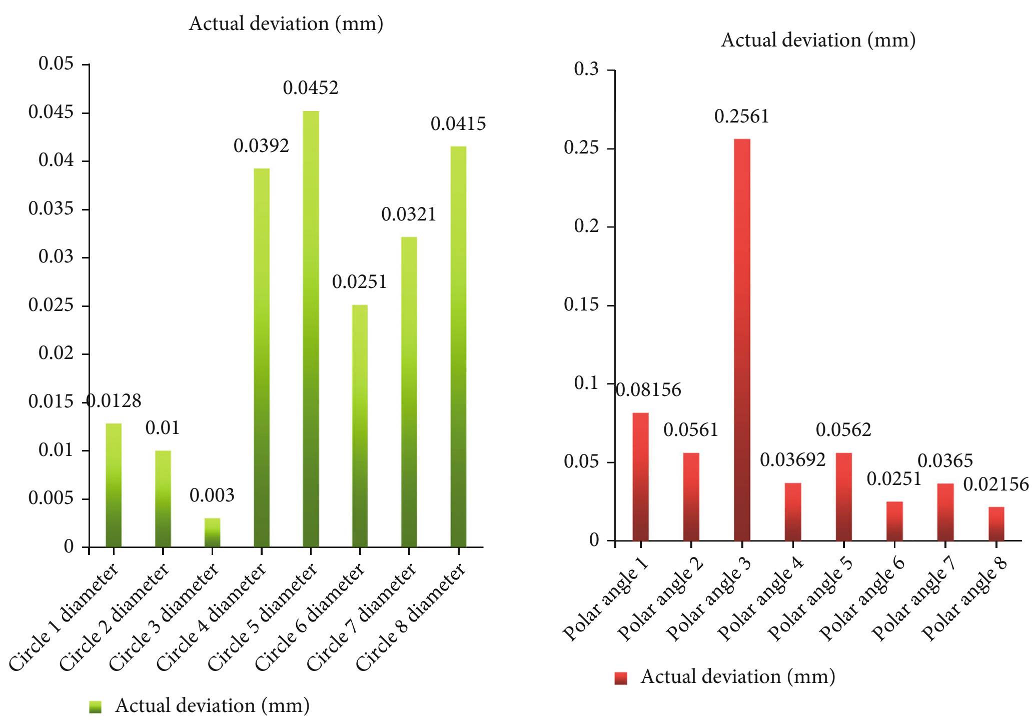

Figure 12: DLP3D printing sample deviation value.

According to Figure 10, we can conclude that the development of 3D printing technology has become faster and faster in recent years, and the annual output value has reached an increase of more than 20%. With the development of 3D printing technology, the development of DLP3D printing technology is also rapid, especially in 2018-2019; the output value has increased by more than 25%.

According to Table 5, a picture of the application of DLP3D printing technology in high-precision automation and other industries can be drawn, as shown in Figure 11.

According to Figure 11, we know that the output value of DLP3D printing technology in the automation and high-density industry has increased year by year in recent years, and in the field of DLP3D printing applications, high-end technology and medical applications are used more, and both accounted for 10%.

4.3. Application Analysis of DLP3D Printing Technology in Automated Precision Manufacturing. Through the investigation of DLP3D printing technology in automated precision manufacturing, the automated precision products printed by DLP3D were measured, and the measurement results are shown in Figure 12.

According to Figure 12, it can be concluded that the deviation value of the material printed by DLP3D based on the embedded microprocessor is generally between 0.01 and 0.1, which is 15.6% lower than that of the material printed by other technologies.

5. Conclusions

This chapter describes in detail the more common 3D printing technologies and their classifications, combined with the existing equipment conditions to print the tooth model of this experiment, and introduces in detail some common algorithms in 3D printing technology; in addition, in the experiment of this article, the samples printed by DLP3D printing technology were analyzed in detail, and finally came to the conclusion of this article: the deviation value of the material and the material of DLP3D printing based on embedded microprocessor is significantly lower than that of other technology printing, which is 15.6%.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

[1] S. Jeschke, C. Brecher, H. Song, and D. Rawat, *Industrial Internet of Things: Cybermanufacturing Systems*, Springer, Cham, Switzerland, 2017, ISBN: 978-3-319-42558-0.

[2] S. B. Tsai, M. F. Chien, Y. Xue et al., "Using the fuzzy DEMATEL to determine environmental performance: a case of printed circuit board industry in Taiwan," *PLoS One*, vol. 10, no. 6, p. e0129153, 2015.

[3] S.-B. Tsai, Y.-C. Lee, C.-H. Wu, and J.-J. Guo, "Examining how manufacturing corporations win orders," *South African Journal of Industrial Engineering*, vol. 24, no. 3, pp. 112–124, 2013.

[4] F. M. Lins, L. A. Tambara, F. L. Kastensmidt, and P. Rech, "Register file criticality and compiler optimization effects on embedded microprocessor reliability," *IEEE Transactions on Nuclear Science*, vol. 64, no. 8, pp. 2179–2187, 2017.

[5] L. T. Clark, D. W. Patterson, C. Ramamurthy, and K. E. Holbert, "An embedded microprocessor radiation hardened by microarchitecture and circuits," *IEEE Transactions on Computers*, vol. 65, no. 2, pp. 382–395, 2016.

[6] I. Hida, S. Takamaeda-Yamazaki, M. Ikebe, M. Motomura, and T. Asai, "A high performance and energy efficient microprocessor with a novel restricted dynamically reconfigurable accelerator," *Circuits & Systems*, vol. 8, no. 5, pp. 134–147, 2017.

[7] D. Chen and G. Qin, "An embedded iris image acquisition research," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 5, no. 1, pp. 90–90, 2017.

[8] X. Wang, M. Jiang, Z. Zhou, J. Gou, and D. Hui, "3D printing of polymer matrix composites: a review and prospective," *Composites Part B Engineering*, vol. 110, pp. 442–458, 2017.

[9] G. Jonathan and A. Karim, "3D printing in pharmaceutics: a new tool for designing customized drug delivery systems," *International Journal of Pharmaceutics*, vol. 499, no. 1-2, pp. 376–394, 2016.

[10] C. Gosselin, R. Duballet, P. Roux, N. Gaudillière, J. Dirrenberger, and P. Morel, "Large-scale 3D printing of ultra-high performance concrete - a new processing route for architects and builders," *Materials & Design*, vol. 100, pp. 102–109, 2016.

[11] B. Gao, N. Xu, and P. Xing, "Shock wave induced nanocrystallization during the high current pulsed electron beam process and its effect on mechanical properties," *Materials Letters*, vol. 237, no. 15, pp. 180–184, 2019.

[12] R. Sato, Y. Hatanaka, Y. Ando et al., "High-speed operation of random-access-memory-embedded microprocessor with minimal instruction set architecture based on rapid single-flux-quantum logic," *IEEE Transactions on Applied Superconductivity*, vol. 27, no. 4, pp. 1–5, 2017.

[13] M. S. Kim, S. H. Song, H. I. Kim, and S. H. Ahn, "Hybrid 3D printing and casting manufacturing process for fabrication of smart soft composite actuators," *Journal of the Korean Society for Precision Engineering*, vol. 33, no. 1, pp. 77–83, 2016.

[14] S. Patra and V. Young, "A review of 3D printing techniques and the future in biofabrication of bioprinted tissue," *Cell Biochemistry & Biophysics*, vol. 74, no. 2, pp. 93–98, 2016.

[15] E. Berdahl and M. Blessing, "Physical modeling sound synthesis using embedded computers: more masses for the masses," *The Journal of the Acoustical Society of America*, vol. 139, no. 4, pp. 2204–2204, 2016.

[16] A. Sasson and J. C. Johnson, "The 3D printing order: variability, supercenters and supply chain reconfigurations," *International Journal of Physical Distribution & Logistics Management*, vol. 46, no. 1, pp. 82–94, 2016.

[17] A. Yz, C. Pla, D. B. Peng, Y. Zeng, and J. Chen, "Investigation on 3D printing ZrO_2 implant abutment and its fatigue performance simulation," *Ceramics International*, vol. 47, no. 1, pp. 1053–1062, 2021.

[18] M. Süvari, U. C. Abuk, Y. Yiit, and O. Dadeviren, "An android-based microprocessor programmer software and interface for embedded systems," *Bilişim Teknolojileri Dergisi*, vol. 11, no. 4, pp. 321–332, 2018.

[19] M. A. Boussadi, T. Tixier, A. Landrault, and J. P. Derutin, "HNCP: a many-core microprocessor ASIC approach dedicated to embedded image processing applications," *Microprocessors & Microsystems*, vol. 47, pp. 333–346, 2016.

[20] S. Ding, S. Qu, Y. Xi, and S. Wan, "Stimulus-driven and concept-driven analysis for image caption generation," *Neurocomputing*, vol. 398, pp. 520–530, 2020.

[21] K. David, "Everspin MRAM targets enterprise new nonvolatile memory attracts storage and embedded customers," *Microprocessor Report*, vol. 30, no. 12, pp. 15–18, 2016.

[22] E. Macdonald and R. Wicker, "Multiprocess 3d printing for increasing component functionality," *Science*, vol. 353, no. 6307, pp. 1512–1512, 2016.

[23] Y. Yang, Y. Chen, Y. Wei, and Y. Li, "3D printing of shape memory polymer for functional part fabrication," *The International Journal of Advanced Manufacturing Technology*, vol. 84, no. 9-12, pp. 2079–2095, 2016.

[24] T. R. Halfhill, "More embedded mergers in 2016 consolidation creates new giants, but some products suffer," *Microprocessor Report*, vol. 30, no. 12, pp. 9–14, 2016.

[25] H. Song, G. A. Fink, and S. Jeschke, *Security and Privacy in Cyber-Physical Systems: Foundations, Principles and Applications*, Wiley-IEEE Press, Chichester, UK, 2017, ISBN: 978-1-119-22604-8.

[26] C. Farnsworth, L. T. Clark, A. R. Gogulamudi, V. Vashishtha, and A. Gujja, "A soft-error mitigated microprocessor with software controlled error reporting and recovery," *IEEE Transactions on Nuclear Science*, vol. 63, no. 4, pp. 2241–2249, 2016.

[27] F. Klift, Y. Koga, A. Todoroki, M. Ueda, Y. Hirano, and R. Matsuzaki, "3D printing of continuous carbon fibre reinforced thermo-plastic (CFRTP) tensile test specimens," *Open Journal of Composite Materials*, vol. 6, no. 1, pp. 18–27, 2016.

[28] D. Chimene, K. K. Lennox, R. R. Kaunas, and A. K. Gaharwar, "Advanced bioinks for 3D printing: a materials science perspective," *Annals of Biomedical Engineering*, vol. 44, no. 6, pp. 2090–2102, 2016.

[29] Z. Lv and H. Song, "Trust mechanism of feedback trust weight in multimedia network," *ACM Transactions on Multimedia Computing, Communications, and Applications*, vol. 17, no. 4, pp. 1–26, 2021.

[30] J. Xie, "A study of fingerprint recognition algorithm of networking embedded system," *Agro Food Industry Hi Tech*, vol. 28, no. 1, pp. 60–63, 2017.

[31] F. C. Godoi, S. Prakash, and B. R. Bhandari, "3d printing technologies applied for food design: status and prospects," *Journal of Food Engineering*, vol. 179, pp. 44–54, 2016.

[32] A. L. Duigou, M. Castro, R. Bevan, and N. Martin, "3D printing of wood fibre biocomposites: from mechanical to actuation functionality," *Materials & Design*, vol. 96, pp. 106–114, 2016.

[33] H. Chen, L. Fang, D. L. Fan, W. Huang, and L. Zeng, "Particle swarm optimization algorithm with mutation operator for particle filter noise reduction in mechanical fault diagnosis," *International Journal of Pattern Recognition and Artificial Intelligence*, vol. 34, no. 10, p. 2058012, 2020.

[34] Z. Alam, F. Iqbal, S. Ganesan, and S. Jha, "Nanofinishing of 3D surfaces by automated five-axis CNC ball end magnetorheological finishing machine using customized controller," *The International Journal of Advanced Manufacturing Technology*, vol. 100, no. 5-8, pp. 1031–1042, 2019.

[35] K. Orlowski, "Automated manufacturing for timber-based panelised wall systems," *Automation in construction*, vol. 109, p. 102988, 2020.

[36] C. Li and Y. H. Huang, "Deep-trained illumination-robust precision positioning for real-time manipulation of embedded objects," *The International Journal of Advanced Manufacturing Technology*, vol. 111, no. 7-8, pp. 2259–2276, 2020.

[37] Z. Weng, J. Wang, T. Senthil, and L. Wu, "Mechanical and thermal properties of ABS/montmorillonite nanocomposites for fused deposition modeling 3D printing," *Materials & design*, vol. 102, pp. 276–283, 2016.

[38] M. Perner, S. Algermissen, R. Keimer, and H. P. Monner, "Avoiding defects in manufacturing processes: a review for automated CFRP production," *Robotics and Computer-Integrated Manufacturing*, vol. 38, pp. 82–92, 2016.

[39] Y. Hou and Q. Wang, "Research and improvement of content-based image retrieval framework," *International Journal of Pattern Recognition and Artificial Intelligence*, vol. 32, no. 12, p. 1850043, 2018.

[40] M. Despeisse, M. Baumers, P. Brown et al., "Unlocking value for a circular economy through 3D printing: a research agenda," *Technological Forecasting and Social Change*, vol. 115, pp. 75–84, 2017.