Research on Optimization of 3D Printing Model Based on Deep Learning

Yidong Lin

Queen Mary College of Engineering, Queen Mary University, London, E1 4NS, United Kingdom

jp2020303946@qmul.ac.uk

Abstract. 3D printing is a process of creating three-dimensional physical objects through a series of layering techniques. It is a relatively new technology, but it has already brought a lot of innovation and change to manufacturing and other fields. This paper introduces the basic mechanism of 3D printer and summarizes several advanced 3D printing model optimization methods based on deep learning and their application scenarios. The proposed approach involves training a deep neural network on a large dataset of 3D models and their corresponding printing parameters. The trained model is then used to detect printing parameters of different 3D models, such as lattice defect detection, laser temperature detection, and fault detection. This method improves printing quality and reduces printing time and material consumption. The experimental results show that these methods are superior to traditional methods and achieve a good balance between print quality and efficiency. The proposed method has great application potential in various fields such as manufacturing, prototyping, and art design.

Keywords: Deep Learning, 3D printer, Detection.

1. Introduction

3D printing technology originated in the 1980s and was initially used to rapidly produce prototype models, but as the technology continues to evolve, it is gradually applied to medical, aviation, automotive and other fields [1]. The main features of 3D printing technology are rapid manufacturing, personalized customization, and strong flexibility in parts manufacturing. At present, 3D printing technology has become an important part of the manufacturing industry, and its application fields are constantly expanding, including medical, aerospace, industrial manufacturing and so on.

This article aims to introduce the 3D printer and some of the current cutting-edge technology development in the field of 3D printing. In recent years, with the 3D printer becoming more and more intelligent, the requirements for the printer are also getting higher and higher, the need for more intelligent, more functional equipment to promote the development of the printer, the second chapter of this article lists several new sensors in the application of 3D printing technology. The third chapter introduces and summarizes some new application scenarios of several deep learning technologies in the 3D printing neighborhood in recent years. With the continuous development and maturity of 3D printing technology, its application in industrial manufacturing is more and more extensive. Through 3D printing technology, rapid manufacturing, personalized customization, and flexible manufacturing can be realized, so as to improve industrial production efficiency and economic benefits.

2. System design scheme

2.1. Introduction and principles of 3D printing

3D printing is a rapid manufacturing technique that builds physical objects from digital models. The principle is to slice the digital model into thin layers and then build the physical object layer by layer. These layers are made of materials inside the 3D printer, such as plastic, metal or ceramics. The 3D printer adds the material layer by layer, according to the digital model instructions, until it eventually forms the entire object.

3D printers usually use several different printing techniques, such as fused deposition modeling (FDM), light curing (SLA), and selective laser sintering (SLS), among others. Among them, FDM is

one of the most used 3D printing techniques. It uses thermoplastic material, extrudes the material through a nozzle, and then adds material on top of each thin layer, gradually building the object. Other techniques use light curing resins, powders, or other materials. In general, 3D printing technology is evolving and being used in a wide variety of fields, such as aerospace, medical, construction and manufacturing. It can not only reduce manufacturing costs and production time, but also enable highly customized and innovative designs.

The process of 3D printing can be divided into three main steps: modeling, slicing, and printing. Modeling is the first step, which involves creating a 3D model using 3D modeling software. 3D modeling software can range from professional CAD software (like SolidWorks, AutoCAD, etc.) to simpler and easier to use software (like Tinkercad, SketchUp, etc.). During the modeling process, you can add details, change dimensions, add supports and structures, etc., as needed. Slicing is the process of turning a 3D model into instructions that a 3D printer can recognize. Slicing software cuts the 3D model into thin slices and converts each slice into instructions that the printer can understand. The slicing software can also control various parameters of the printer, such as print speed, temperature, fill density, and support structure, among others. The slicing software generates a G-code file, which contains all the instructions required for the 3D printer. During the printing process, the 3D printer will follow the instructions in the G code file layer by layer. During the printing process, the printer will spray out the hot plastic and place it in precisely the right place through a series of movements. The printer prints layer by layer until the entire model is complete. When finished, the printed item can be removed from the printer and subsequent processing (such as removal of support, sanding, painting, etc.) can be done.

2.2. Sensor collection

2.2.1 Frame structure

The frame is the main structure of the 3D printer, usually made of aluminum, steel or plastic materials. The design of the frame is directly related to the stability and accuracy of the 3D printer. The second part of the print head is the core part of the 3D printer, which is used to spray out the melted material and build the object. The print head is usually composed of a nozzle, a hot end, and a cooling fan. The third part of the printing platform is a flat surface on the 3D printer that is used to support the object being printed. The printing platform is usually made of materials such as glass, aluminum plate or graphite plate, and its temperature can be controlled by heating, cooling, etc., to ensure that the object can be firmly adhered to the platform during the printing process. 3D printers require multiple motors and the transmission system. to control the movement of the print head and printing platform. These motors and transmission systems, including stepper motors, transmission belts, slide rails, etc., constitute the fourth part. 3D printers require an electronic control system to control the movement and operation of individual components. The control system includes motherboard, power supply, relay, controller, etc. This is the fifth part of the 3D printer. These are the main components of a 3D printer, and different models and brands of 3D printers may have different structures and components. The 3D structure diagram is shown in Figure 1 below.

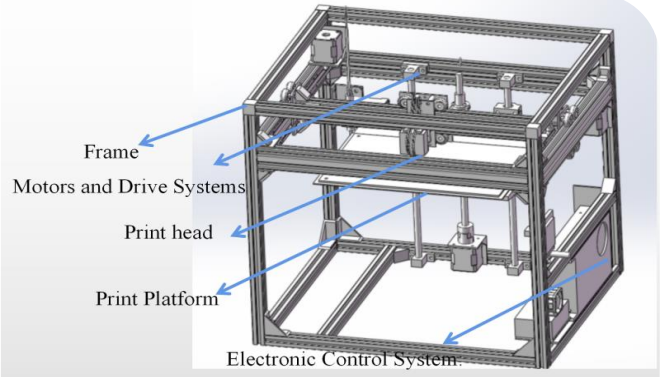


Figure 1. 3D structure diagram

2.2.2 Sensor

An electronic temperature sensor is a sensor inside a 3D printer that detects temperature and converts it into a usable output signal that can be displayed on an electronic screen. There are three common types of temperature sensors: thermocouples, thermistors, RTDs and IC temperature sensors. The basic principle of these sensors is the same: they output the sensed data signal to an electronic display through the sensing of a hot spot, thus enabling data transmission and processing. While manufacturing a model usually takes a few small inches or degrees of complexity, 3D printing takes a few hours, depending on the performance of the printer, of course. This ensures that the temperature information is reflected to the 3D printer in time.

Based on how 3D printing works and how an electrical temperature sensor works, electronic temperature sensors are incorporated into the 3D printing process. It needs a manufacturing model. The printing of three dimensions. By adjusting the temperature, 3D printing can model 3D objects and manage their color. Enough (on curved surfaces, possibly, to obtain goods with a greater resolution, to increase 3D printing's precision and effectiveness. Though it is still young, 3D technology is becoming more useful.to somewhat larger items with printers. There are still significant restrictions on color and line formation, though. The cause of this is that a pre-programmed printing technique, which pays little attention to color, controls most of the printing process. This issue may be effectively solved by the electronic temperature sensor's sensitivity and timely data transmission, which will allow for real-time environmental monitoring and prompt delivery of pertinent information to the electronic screen. The computer will then use this information to adjust the printed coloring in a timely manner after receiving it, greatly enhancing the final product's quality [2].

Pressure sensor: A sensor is required for 3D printing in order to detect the print's position and supply coordinates for the subsequent print. After the print head touches the print bed several times (the more points touched, the higher the accuracy), the pressure sensor senses the signal sent to the input and output ports and then to the system. After the pressure sensor senses it, the system automatically remembers it and generates the relative coordinate plane to serve as the coordinate system for the subsequent print.

Most conventional 3D printers lack a leveling function, and those that do it using photoelectric sensors and mechanical print head activity, which has the drawback of reducing print head precision and making it insensitive. often the root of printing issues. Performance: neither sticky nor head-plugging. The new Anming pressure sensor not only corrects photoelectric sensor flaws but also makes automation, program control, and touch automatically leveling functions possible [3].

2.3. Control System

The heart of a 3D printer and the control hub for the entire 3D printing process is the central control system. By examining the matching command tasks, receiving sensor data, managing the mechanical structure, stepping motor, and other hardware, which is mostly made up of the control motherboard, motor and drive, hot bed, and sensor, it completes the 3D workpiece structure forming [4].

The control motherboard is the core part of the 3D printer, which is responsible for receiving the instructions from the computer and translating them into control signals such as the action of the motor and the temperature of the hot bed. There are usually some common interfaces on the control motherboard, such as USB, SD card, LCD display screen, etc., so that users can easily control and monitor the running status of the printer.

The motor and drive are an important part of the 3D printer, they are responsible for controlling the movement of the print head and the hot bed. Printers typically require at least 3 motors that control the movement of the X, Y, and Z axes, respectively. Each motor requires a corresponding driver, which is responsible for converting the control signal into the rotation of the motor.

A hot bed is an important part of a 3D printer, which improves the adhesion and flatness of the printed material. The hot bed requires a temperature sensor and a heater through which the control motherboard controls the temperature of the hot bed.

The sensor helps control the motherboard by monitoring various parameters during the printing process, such as temperature, speed, position, etc., to dynamically adjust the printing parameters to improve the printing quality and efficiency. Common sensors include thermistors, photoelectric switches, limit switches and so on.

In addition to the above several parts, the control system of the 3D printer also includes some other components, such as fans, LED lights and so on. These parts can help improve print quality and stability, or provide the necessary light and ventilation during the printing process.

3. Deep learning application scenario analysis

3.1. Defect detection

The multifunctional dot-matrix structure is essential for achieving the big size, high strength, and light weight specifications for aeronautical components [5, 6]. In the process of creating dot-matrix structures, errors are unavoidable, and these errors will significantly lower the structures' performance and dependability. To inform the production of dot matrix structures and the evaluation of their state of health, it is crucial to comprehend the nature and distribution of flaws. Due to the internal structure of the dot matrix's high porosity and complexity, structural tomography pictures are frequently obtained using industrial CT technology and 3D reconstruction, and CT images are manually reviewed to identify defects. The inspection results are, however, very subjective, ineffective, and have a high rate of missed and false detections when inspectors are confronted with a large number of CT scans and are emotionally and physically exhausted. There aren't many studies on automatic flaw detection techniques for 3D printed metal dot matrix structures, and there aren't any established, effective standards or technique.

Deep learning has been used for various picture identification problems as a result of its widespread success in the target detection sector [7, 8]. The automatic detection of flaws inside the dot matrix structure is accomplished via a novel approach based on the YOLOv3 deep learning algorithm for intelligent inspection of CT images, which creates a corresponding multi-scale defect prediction model gotten by Zhang Yuy an, Ren Ten gfe i, Wen Yintang. According to the trials, this method can precisely identify and locate two common fusion defect manifestations within the metal dot matrix structure, and its average accuracy is 0.957 with good real-time performance and high precision [9].

3.2. Laser spot temperature detection

The manufacturing technique called 3D printing heats the material layer by layer using a laser beam as a heat source to create solid parts directly from 3D model data [10]. The precision and quality of 3D printed parts are significantly impacted by the laser spot temperature. The part may be abraded if the laser temperature is too high; on the other hand, if the temperature is too low, internal flaws and dimensional problems may result. To increase the precision and quality of the item, it is crucial to research the laser spot's temperature distribution. However, the laser beam's high temperature, brightness, small size, and intricate thermal process make it difficult to use.

The two primary types of traditional laser spot temperature detection are contact and non-contact. Thermocouples and other sensors are typically used in contact measurement [11], but the measurement outcomes are subpar due to the high laser temperature and tiny size. The principal non-contact measurement tools are pyrometers, CCD industrial cameras, and other devices [12]. Because of the noise in CCD image data gathering and processing, substantial system errors are frequently produced.

The science of artificial intelligence has advanced, and several different deep learning techniques are now in use. A recent study suggests a method for detecting laser temperature fields based on convolutional neural networks, which involves collecting a large number of images of laser temperature radiation, training the network on the training set, applying the trained model to the test

set, and determining the center point temperature of the test laser image. The method has been shown to be workable [13].

3.3. Troubleshooting 3D Printing

A potential additive manufacturing technique called 3D printing employs digital model files as the foundation for layer-by-layer printing of things or products [14]. According to the drive structure, common 3D printers can be classified as parallel and tandem 3D printers. The parallel mechanism 3D printer has the advantages of compactness, light weight, good stiffness, and high drive precision, but the tandem mechanism 3D printer offers a greater motion space [15]. Regardless of the drive mechanism, a 3D printer's drive precision may deteriorate over time. The universal ball bearings and synchronous belts in the drive chain of parallel-arm 3D printers, for instance, may wear down or degrade, leading to drive gaps that may impair the quality of the final print. Mechanical drive precision is one of the most crucial variables, even if there are many other factors that affect the quality of 3D printing [16]. Therefore, troubleshooting geared for 3D printing is crucial for ensuring print accuracy and quality.

The application of fault diagnosis techniques to common mechanical systems, including gears, bearings, and other rotating machinery, has proved effective [17]. Commercial 3D printers are price-sensitive, and extremely sensitive troubleshooting sensors are expensive and challenging to market, which present a hurdle for marketable 3D printer troubleshooting. In comparison to these common mechanical systems, 3D printers are compact and complex in motion.

Many big data researchers in the field of fault diagnosis have confirmed the effectiveness of deep learning, a big data-based fault diagnosis technique [18]. Unsupervised training (pre-training) and supervised learning (fine-tuning) are the two learning processes that make up the heart of deep learning. The performance of deep learning on massive data is significantly enhanced by this two-stage learning strategy. The proper deep network topology and the proper classifier have been the subject of research in deep learning-based defect diagnosis approaches [19]. Recent research has proposed a suboptimal deep learning network with additional two-stage categorization (Pre-classifying and Fine-classifying), which adaptively determines an inadequate network structure with better performance on the one hand and further improves the performance of the deep learning network on the other. These researchers were inspired by two-stage deep learning methods, including Pre-training and Fine-tuning. On the other hand, we enhance the deep learning network's capability to classify device states. Using a parallel-arm 3D printer as an example, the experimental testing of the suboptimal network deep learning to make up for the hardware shortage of consumer-grade pose sensors lays the groundwork for improving the commercial applicability of 3D printing fault diagnosis and shows the feasibility [20].

4. Conclusion

With the development of deep learning algorithms and intelligent sensors, 3d printing technology is also developing rapidly in this case, deep learning algorithms also have more and more applications in the 3D printing neighborhood, such as defect detection, temperature detection, fault detection, etc., which can better improve the existing problems of 3D printing technology and better promote the development of 3D printing technology.

This paper summarizes some application scenarios and feasibility of some advanced deep learning algorithms and intelligent sensors in the field of 3D printers. The application of these advanced technologies to solve the problems that still exist in 3D printing technology will be a major innovation in related fields, which will continue to promote the development of 3D printing industry and further impact the traditional printing industry. It has injected new momentum into the current information age, so that emerging technologies such as 5G network, Internet of Things, and cloud technology have found strong support points. The application prospect of combining deep learning algorithms

and 3D printing technology is very broad. In the future, there will be more and more hybrid methods of algorithms to solve more problems in the field of 3d printing.

References

[1] Gu Bo. Application and Development trend of additive Manufacturing technology at home and abroad. Metal Processing (Thermal Processing),2 022, 846 (03): 1-16.

[2] Cheng Qian. Design Principle of electronic temperature sensor based on 3D printing. Chinese and Foreign Entrepreneurs,2015, 499 (17): 211.

[3] 3D printer automatic leveling system V1.0 based on pressure sensor. Beijing, 3D Tiangong, 2015.

[4] Lin Xinghan. Overview of 3D Printing Central Control System. Mechanical Design and Manufacturing Engineering, 2023, 52 (01): 1-6.

[5] Thompson A, Maskery I, Leach R K. X -ray computed tomography for additive manufacturing: a review. Measurement Science & Technology, 2016, 27 (7): 072001.

[6] Kang D, Park S, Son Y, et al. Multi**-**lattice inner 12 Quantitative Journal January 2022 structures for high strength and lightweight in metal selective laser melting process. Materials and Design, 2019, 175 (10): 77-8.

[7] Cheng S H, M a J Y, Zhang S J, et al. Smoke Detection Algorit hm Combined with Imp roved Gaussian M ixtur e and YOLOv2. Act a Metrologica Sinic, 2019, 40 (5): 798-803.

[8] Zhang S H, Geng Y, Zhang X W. Using BP Network for Occlusion Boundary Detect Ion Based on Depth Image. Act a Metrological Simic, 2020, 41 (10): 1205-1211.

[9] Zhan g Yuy an, Ren Tengfei, Wen Yintang. A 3D print in g lattice structure defect identification met hod based on YOLOv3 algorithm. Act a Metrologica Sinica,202, 43 (01):7- 13.

[10] Zhang Ronghua, SONG Lijun. Real-time Monitoring and Control of molten pool temperature in laser additive manufacturing. Applied Laser, 2018, (1): 13.

[11] Cheng Honggang, Chen Xiong, Ju Yutao, et al. Experimental Study on Temperature Prediction Method Based on Thermocouple Dynamic Characteristics. Solid Rocket Technology, 2012, (6): 842.

[12] Zhang Fan, Niu Yanxiong, Liu Ning, et al. Study on temperature field and thermal stress field of CCD irradiated by laser. Laser Technology, 2017, (3): 433.

[13] Han B. Laser point temperature detection method of 3D printer based on improved Convolutional neural network. Industrial metrology, 2023, (02): 96-99+112.

[14] Mohammed M I, Gibson I. Design of three-dimensional, triply periodic unit cell scaffold structures for additive manufacturing. Journal of Mechanical Design, 2018, 140 (7): 071701.

[15] Chang Dingyong, Fang Yuefa, YE Wei. Design and analysis of a double output 3D printing decoupling parallel manipulator. Journal of Mechanical Engineering, 2017, 53 (7): 39-46.

[16] Miller D B, Glisson W B, Yampolskiy M, et al. Identifying 3D printer residual data via open-source documentation. Computers & Security, 2018, 75: 10-23.

[17] Shen CQ, Wang D, Kong F R, et al. Fault diagnosis of rotating machinery based on the statistical parameters of wavelet packet paving and a generic support vector regressive classifier. Measurement, 2013, 46: 1551-1564.

[18] Zhao R, Yan R, Chen Z, et al. Deep learning and its applications to machine health monitoring. Mechanical Systems and Signal Processing, 2019, 115: 213-237.

[19] Hinton Ge, Salakhudinov R. Reducing the dimensionality of data with neural networks. Science, 2006, 313: 504-507.

[20] Li Chuan, Zhang Shaohui, Jose Valentede Oliveira. 3D Printer Fault Diagnosis based on Sub-optimal Network Deep Learning. Chinese Journal of Mechanical Engineering, 2019, 55 (07): 73-80.