Using Scanner and Algorithm to Improve the Accuracy of Fused Deposition Modeling Printer

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Abstract. This essay explores the application of laser sensors and algorithms to enhance the accuracy of Fused Deposition Modeling (FDM) Three dimensions (3D) printers. Laser sensors, combined with advanced algorithms, provide a promising solution for improving the accuracy of FDM printers. The essay discusses the limitations of traditional FDM printers in achieving high precision and outlines the significance of accuracy improvement in 3D printing. It then explores the principles and functioning of laser sensors. By analyzing real-time sensor measurements, algorithms can identify errors, compensate for mechanical inaccuracies, and adjust the printer's motion to ensure precise printing. Additionally, the essay discusses the advantages and challenges of incorporating laser sensors and algorithms into FDM printers. The benefits include improved print quality, enhanced compatibility with complex geometries, and reduced dependency on manual calibration. However, challenges such as cost, sensor integration, and algorithm optimization must be addressed for specific adoption or further development. The integration of laser sensors with advanced algorithms offers a promising pathway for achieving high precision and detail in printed objects, ultimately advancing the capabilities and applications of FDM technology.

Keywords: FDM laser sensors, 3D printer, Algorithm.

1. Introduction

With the development of production technology, traditional production models are gradually being phased out. 3D printing, with its high efficiency, low waste, and strong plasticity, plays an increasingly important role in industrial production and has wider applications. And there are many types of 3D printing technologies such as FDM, Stereo Lithography Appearance (SLA), Selected Laser Sintering (SLS), etc., and FDM is the most used one. FDM is the abbreviation of "Fused Deposition Modeling", which is a method of heating, melting, and stacking various wire materials [1].

This paper mainly analyzes the advantages and disadvantages of FDM3D printers and proposes methods to improve their accuracy. The second chapter of this paper is about some basic content of the FDM 3D printer, analyzing it from three aspects: the important components of FDM, working principle, and some current shortcomings, so that readers have a basic understanding of FDM and realize the importance of our research content. The third chapter of this article introduces our proposed optimization plan to improve the printing accuracy of FDM, which combines laser sensors and algorithms to improve accuracy. A detailed and concise flowchart is provided for readers to understand, and optimization cases are provided to verify the reliability of our method. Although there have been some encouraging results in the research on FDM3D printers, the drawbacks of this type of printer are still obvious. If these drawbacks can be addressed, it can greatly reduce production costs and improve production efficiency. Obviously, this is of great significance for accelerating the development of industry and promoting the progress of production models. And this is precisely the intention and original intention of our research group.

2. Basic Content of FDM 3D printer

There are many types of 3D printing technologies such as FDM, SLA, SLS, etc., and FDM is the most used one. FDM is the abbreviation of "Fused Deposition Modeling", which is a method of heating, melting, and then stacking various wire materials into shapes

2.1. Key Structures of FDM 3D printer

A FDM 3D Printer is composed of several key components: the material spool, heater element, heating nozzle, support material, and build platform. The Structures of FDM 3D printer is shown in figure 1.

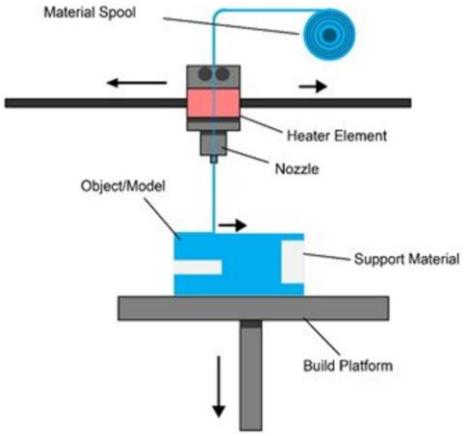


Figure 1. Key Structures of FDM 3D printer [2]

The material spool functions as a wire supply mechanism designed to send the thermoplastic filamentous material to the heating nozzle so that the material can be use. The heating nozzle, as described by Smith and Johnson, receives the thermoplastic filamentous material, heats it to a semi-molten state, and precisely deposits it onto the build platform [2]. According to Anderson and Brown, the support material is used to reinforce the shape of the model during the printing process, preventing deformation and ensuring better structural integrity [3]. Finally, the build platform acts as a workbench where the material is positioned and shaped by the 3D printer, ultimately transforming into a fully realized three-dimensional product part.

2.2. The working principle of FDM 3D printer

The working principle of the FDM 3D printer is simply that the heating nozzle is controlled by a computer, and based on the cross-sectional profile information of the product parts, it moves in the X-Y plane, which is shown in figure 2.

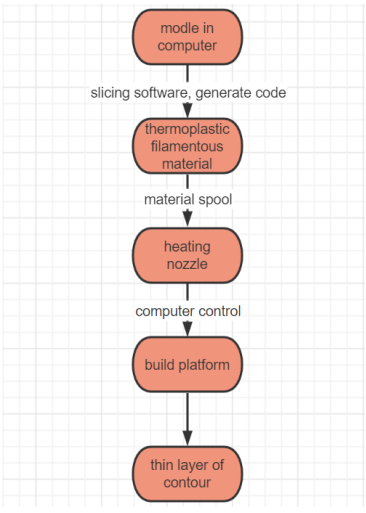


Figure 2. The working principle of FDM 3D printer (Photo/Picture credit: Original)

The thermoplastic filamentous material is sent to the hot melt nozzle by the material spool (wire supply mechanism), heated and melted into a semi liquid state in the nozzle, and then squeezed out. It is selectively coated on the build platform, and quickly cooled to form a thin layer of contour about 0.127mm thick. After the completion of the first layer of cross-section molding, the build platform descends to a certain height, and then the next layer of cladding is carried out. And then the 3Dprinter works in this cycle and in the end, it forms a three-dimensional product part

2.3. The challenges of FDM 3D printer

FDM printers often face challenges related to layer height, thermal contraction, and layer adhesion, which can affect the level of detail, dimensional accuracy, and surface finish of printed objects. Larger layer heights are chosen to expedite print times but may compromise precision, while smaller layer heights enhance accuracy [4].

Thermal contraction during the cooling process can result in dimensional deviations, shrinkage, and warping of FDM parts. To mitigate these issues, preheating build plates or utilizing heated chambers can minimize temperature differentials and ensure uniform cooling, thus enhancing dimensional stability [5].

Weak bonding between layers can lead to reduced structural integrity and visible artifacts on the print surface. Several factors influence layer adhesion, including print settings, material properties, and environmental conditions. Optimizing parameters such as extruder temperature, print speed, and infill density can significantly improve layer adhesion and overall print quality [6].

The surface of prototypes printed by FDM often exhibits noticeable stripes, and the molding accuracy is relatively low, with a maximum accuracy of 0.127mm. These limitations highlight the importance of addressing issues related to layer height, thermal contraction, and layer adhesion to achieve higher levels of precision and surface quality in FDM printing.

3. Optimization method

3.1. Hardware and software

Nowadays, researchers witnessed remarkable advancements in 3D printer hardware, particularly the introduction of laser sensors and the implementation of intelligent fine-tuning technology. These enhancements have revolutionized the printing experience by minimizing errors and inconsistencies in the printing process.

Laser sensors play a crucial role in various technological applications, including 3D printing. They function by scanning the topmost layer of a design and generating digitized information. This scanned pattern is then analyzed to identify any deviations from the intended design, resulting in error values that provide valuable feedback [7]. By accurately detecting errors, laser sensors enable precise adjustments, ultimately enhancing the overall printing quality. Their ability to capture intricate details and facilitate iterative improvements makes them indispensable in achieving optimal precision and accuracy in 3D printing [8].

During the scanning process, laser sensors capture the surface of the printing material and generate error values that represent variations from the intended design. These error values can be plotted as line graphs, providing a visual representation of the discrepancies encountered [9]. By analyzing these data points, necessary micro-adjustments can be made to improve printing accuracy. This analysis and adjustment process ensures that subsequent layers are printed with increased precision, resulting in high-quality output.

Motor systems, on the other hand, are responsible for enabling smooth and precise movements in 3D printers. Stepper motors, located outside the printer's enclosure, ensure uninterrupted printing operations. Using specialized motors and a belt mechanism, the printer can perform rotational movements and precise vertical motion within the build volume [10]. These movements are crucial for annular scanning, ensuring even layer coverage and enabling real-time analysis during the printing.

The addition of laser sensors enables real-time mapping and scanning of the top surface of the printing material. The collected data is then transmitted to a programmed microcontroller, which extracts error values from the original linear data. By eliminating these error data points, the microcontroller can compare the mean value to a predefined threshold value. The detail of the analysis program will be discussed later in the paper.

In conclusion, laser sensors and motor systems play pivotal roles in enhancing the precision and functionality of 3D printers. Laser sensors enable pattern scanning, error analysis, and micro-adjustments, improving printing accuracy. Motor systems facilitate rotational movements for annular scanning and ensure precise vertical motion along the Z-axis. By understanding the integration and operation of these components, we gain insight into the complex machinery behind successful 3D printing technology.

3.2. Optimization Case

3.2.1 Enhancing Accuracy with Laser Sensors

Laser sensors have emerged as a pivotal component within 3D printers, enabling the scanning of patterns on the topmost layer of the printing material. During this process, the laser sensor captures and analyzes data, generating error values that indicate any deviations from the intended design. These error values are then plotted as line graphs, providing a visual representation of the variations encountered during the scanning process.

The collected data points are meticulously analyzed to identify and rectify any erroneous issues. By comparing the error values, precise micro-adjustments can be made to optimize printing accuracy. Through the elimination of error data points, a programmed microcontroller calculates the mean value and compares it to a predefined threshold value. This meticulous analysis and adjustment process ensure subsequent layers are printed with utmost precision, resulting in high-quality output [8].

3.2.2 Motor Systems for Seamless Movement

Motor systems are a vital component of 3D printers, providing both rotational movement and precise vertical motion. Stepper motors, positioned outside the printer's enclosure, ensure uninterrupted printing operations. These motors are intricately connected to the print head through a belt mechanism, enabling precise up and down movements within the printer's build volume [4].

To commence the printing process, the stepper motors perform an initial scanning motion along the X and Y-axis, precisely determining the position for each layer. Once the desired layer is located, the stepper motor halts, and the printing operation commences. This initial scan guarantees accurate alignment and positioning, forming the foundation for impeccable printing [2].

Moreover, the stepper motor executes rotational motion to facilitate annular scanning of the identified layer. This rotational movement ensures even layer coverage and enables real-time analysis during the printing process. The incorporation of specialized motors allows for seamless rotation while the printer remains stationary, significantly enhancing the efficiency and accuracy of the annular scanning process.

3.2.3 Exemplifying Enhanced Printing Precision

To exemplify the impact of laser sensors and motor systems on 3D printing precision, let us consider an enlightening case study. A dedicated research team aimed to optimize the printing accuracy of complex geometric designs. By implementing state-of-the-art laser sensors and motor systems, they achieved remarkable results.

The laser sensors provided real-time mapping and scanning of the top surface of the printing material. This invaluable data was transmitted to a precisely programmed microcontroller, facilitating error analysis and micro-adjustments. By continuously monitoring and optimizing the printing process, the team significantly reduced printing errors, thereby elevating the overall precision [4].

The integration of motor systems enabled precise rotational and vertical movements. The stepper motors ensured accurate alignment and positioning of each layer, while the rotational motion

facilitated annular scanning. Consequently, the research team achieved consistent layer coverage and effectively minimized printing inconsistencies, resulting in a remarkable output quality.

4. Conclusion

This article mainly discusses the basic content and optimization methods of FDM 3D printers. The research provides a detailed introduction to the key structures, working principle, and challenges of FDM 3D printers. The basic content of FDM 3D printers includes their key structures and working principle, which play a crucial role in ensuring accuracy and stability during the printing process. However, FDM 3D printing technology still faces some challenges, with one of the primary challenges being the improvement of printing precision. Factors such as material characteristics and mechanical structures may lead to certain errors and instability during the printing process.

To overcome these challenges, this article introduces several optimization methods aimed at enhancing the performance and precision of FDM 3D printers. The article particularly focuses on both hardware and software aspects. By employing advanced hardware technologies, such as laser sensors and sophisticated motor systems, the accuracy and seamless movement of the printer can be effectively improved. Additionally, software algorithm enhancements can further enhance printing precision and efficiency.

In conclusion, FDM 3D printing technology is continually evolving and optimizing. Despite facing challenges, through hardware and software optimization, significant improvements in printing precision and performance can be achieved. This research provides robust support for the further development and application of FDM 3D printing technology.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

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