International Journal of Pure and Applied Mathematics
Volume 116 No. 3 2017, 789-797
ISSN: 1311-8080 (printed version); ISSN: 1314-3395 (on-line version)
url: http://www.ijpam.eu
doi: 10.12732/ijpam.v116i3.24

ijpam.eu

ANALYSIS AND MANAGEMENT OF THE LOCATION OF THE OBJECT IN THE PROBLEMS OF THE VIRTUAL CAMERA SETTING IN THE TECHNOLOGIES OF ADDITIVE PRODUCTION

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Abstract: Additive production is used in medicine, cosmonautics, production of finished products and for other processes. Therefore, the presented research has its importance and is relevant. Based on the relevance, the purpose of the work is to analyze and manage the location of the object in the tasks of configuring the virtual camera in additive production technologies. To solve the set task, the system method was used in the work, which allowed to analyze the location of the object, in the process of using additive production.

The results show that the correct location of the part in the chamber allows the software tool to be realized and to identify errors in the output to the press, which will save time and material.

AMS Subject Classification: 03C15, 68P01

Key Words: additive manufacturing, computational methods, normal, surface quality, normals analyzing

Received: July 24, 2017
Revised: September 4, 2017
Published: October 27, 2017

1. Introduction

Additive production (or 3D printing) is the process of creating solid three-dimensional objects of any geometric shape based on the digital model. 3D-printing is based on the concept of constructing an object by successively applied layers that represent the contours of the model. In fact, 3D printing is the complete opposite of such traditional methods of mechanical production and processing as milling or cutting [1].

Although 3D-printing technology appeared in the 80s of the last century, 3D printers gained wide commercial distribution only in the beginning of 2010. 3D printing technologies are used for prototyping and distributed production in architecture, construction, industrial design, automotive, aerospace, military-industrial, engineering and medical industries, bioengineering, fashion and footwear production, etc [2].

2. Materials and Methods

Additive production involves the technology to create objects by applying sequential layers of material, which is a time-consuming process. Therefore, in the work for a comprehensive analysis of this process, a system analysis was used.

System analysis is a scientific method of cognition, representing a sequence of actions to establish structural relationships between variables or elements of the system under study. It, in turn, relies on a set of general scientific, experimental, natural-science, statistical, mathematical methods.

To solve the set tasks, methods of structuring and restructuring, algorithmization, modeling, program management, and regulation were used.

Using the modeling method, a study of the processes was carried out in the work by constructing and studying the presented models. For example, this was used in the study of losses in the quality of the surface, which are due to the deviation of the geometry of the layered representation from the original rim of the part.

The main methods of additive production are presented in the table 1.

3. Results and Discussion

The process of technological preparation of any begins with the location of the geometric model of the part in the geometric model of the camera of the

Table 1. Characteristics of additive production methods

Method	Technology	Materials Used
Extrusion	Modeling by the method of layer-by-layer fusing (FDM or FFF)	Thermoplastics (such as polylactide (PLA), acrylonitrile butadiene styrene (ABS), etc.)
Wire	Manufacture of arbitrary forms of electron beam melting (EBF_3)	Practically any metal alloys
Powder coating	Direct laser sintering of metals (DMLS)	Practically any metal alloys
	Electron beam melting (EBM)	Titanium alloys
	Selective laser melting (SLM)	Titanium alloys, cobalt-chromium alloys, stainless steel, aluminum
	Selective thermal sintering (SHS)	Powder thermoplastic
	Selective laser sintering (SLS)	Thermoplastics, metal powders, ceramic powders
Jet	Inkjet 3D printing (3DP)	Gypsum, plastics, metal powders, sand mixtures
Lamination	Fabrication of objects by the method of lamination (LOM)	Paper, metal foil, plastic film
Polymerization	Stereolithography (SLA)	Photopolymers
Digital LED projection (DLP)	Digital LED projection (DLP)	Photopolymers

printing equipment.

The location of the part in the chamber is affected by many factors that ultimately affect the cost and time of printing. For example, the amount of material required depends on the height of the part in the chamber. The orientation of the part affects the printing time, its cooling and possible temperature deformations, the amount of support structures required, etc. The importance of these parameters depends on the specific printing technology and material used. Nevertheless, in all layer-by-layer technologies, the quality of the resulting surface depends on its angle of inclination. All layer-by-layer technologies operate with a layer-by-layer representation of the model, which is in fact a technological approximation of the original part. Losses in the quality of the surface are due to the deviation of the geometry of the layered representation from the original rim of the part [3].

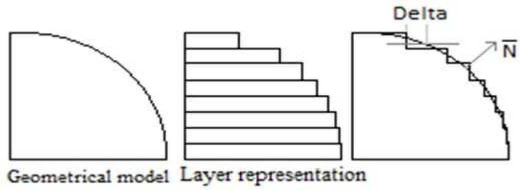

Figure 1: The difference (delta) between the geometry of the layered representation and the original bypass, depending on the normal (N) of the surface

The deviations of the layer representation from the original geometry are the greater, the larger the angle between the normal to the surface and the vertical axis differs from 90°. Thus, from the point of view of the quality of the reproduced surface, the orientation of the part during printing will be better, the more surfaces there are for which the angle between the normal and the vertical is closer to 90°.

Models of 3D printers using selective laser sintering (fusion) technologies present on the market and their characteristics.

The intersection area will be:

$$S = S_1 + S_2 \tag{1}$$

$$S_1 = \frac{R_1^2 * (F_1 - \sin(F_1))}{2} \tag{2}$$

$$S_2 = \frac{R_2^2 * (F_2 - \sin(F_2))}{2}, \tag{3}$$

where:

$$F_1 = 2 * acos \frac{R_1^2 - R_2^2 + D^2}{2 * R_1 * D} \tag{4}$$

$$F_2 = 2 * acos \frac{R_2^2 - R_1^2 + D^2}{2 * R_2 * D} \tag{5}$$

The total area of three-dimensional figures is:

$$S = p^2 tg\frac{a}{2} tg\frac{\beta}{2} tg\frac{\gamma}{2} \tag{6}$$

For models with simple geometry, the machine's optimal positioning problem is solved by the machine operator, but on complex parts the correct arrangement is not obvious. To estimate the quality of the surface at the output, one can use the diagram of the distribution of the areas of surfaces along the angle between the normal and the vertical. According to this diagram, it is possible to estimate the surface distributions by zones and to estimate the area of surfaces falling into zones with poor surface quality.

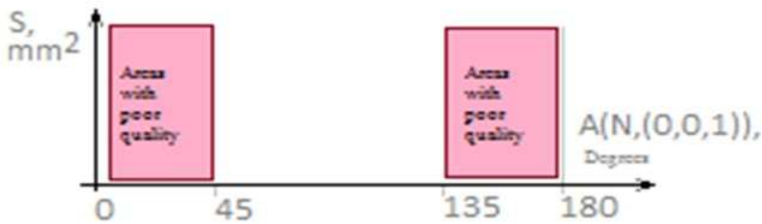

Figure 2: Zones with poor surface quality in the distribution diagram of areas by the angle between the normal and the vertical

The area of zones with poor quality is:

$$S = ab = \frac{1}{2} d_1 d_2 \sin\phi, \;\; d_1 = d_2. \tag{7}$$

Let us consider diagrams of distribution of quality of a surface on an example of a blade. With a horizontal arrangement.

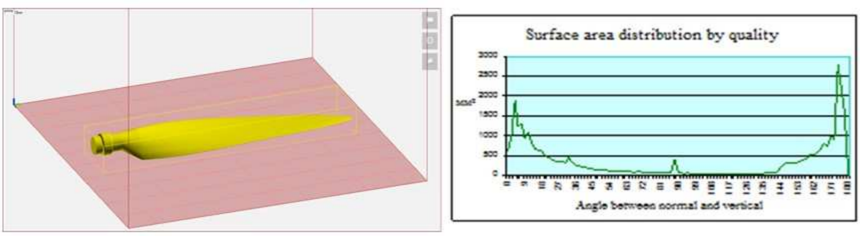

Figure 3: Blade with a horizontal location in the printer's chamber and the distribution of its areas along the normal to the vertical

Based on the area distribution diagram it follows that the detail is very unsuccessful, because Most of its surfaces fall on printing areas with poor surface quality. In practice, it turns out that the part after printing will have a surface with pronounced steps on most surfaces. By integrating the graph over the zones, we find that 58% of the surfaces with this arrangement lie in the zones with poor quality.

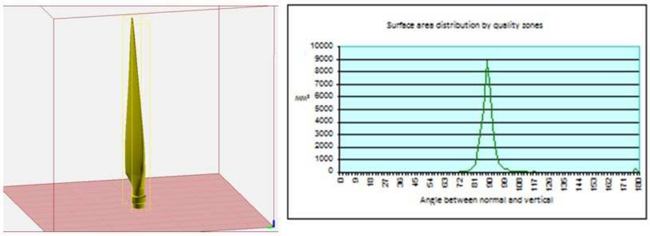

Figure 4: Blade with a vertical arrangement in the printer's chamber and the distribution of its areas along the normal to the vertical

With the vertical location of this part, the vast majority of surfaces lie in the printable area with a high quality surface. If you omit other criteria, then the vertical location of this part in terms of surface quality is preferable:

$$C \cdot X \cdot A = B \tag{8}$$

$$X = \begin{pmatrix} x_1 & (2-3x_1)/4 \\ x_3 & (9-4x_1)/3 \end{pmatrix} \tag{9}$$

Consider the task of automatically optimizing the location of the part in the chamber in terms of the quality of the surfaces [4].

The model M is represented by the set of triangles t_i forming the closed surface of the model.

$$M = \{t_i\},\ I = 1..n. \tag{10}$$

For each triangle, its area s_i and its normal angle n_i with vertical a_i.

$$S = \sqrt{p * (p-a) \times (p-b) \times (p-c)} \tag{11}$$

$$p = \frac{(a+b+c)}{2} \tag{12}$$

$$S = \frac{1}{2} \cdot b^2 \cdot \frac{\sin(a) \cdot \sin(\gamma)}{\sin(\beta)} \tag{13}$$

$$s_i = S(t_i) \tag{14}$$

$$a_i = a \cdot (n_i \cdot (0,01)). \tag{15}$$

The normal to the triangle is calculated as a vector product of vectors constructed on its two edges, so if the triangle

$$t_i = \{(x_1, y_1, z_1), (x_2, y_2, z_2), (x_3, y_3, z_3)\}, \tag{16}$$

Then, we have

$$n_i = (n_x, n_y, n_z) = [(x_1 - x_2, y_1 - y_2, z_1 - z_2), (x_1 - x_3, y_1 - y_3, z_1 - z_3)] = \\ = \begin{vmatrix} i & j & k \\ x & y & z \\ 1 - x_2 & 1 - y_2 & 1 - z_2 \\ x & y & z \\ 1 - x_3 & 1 - y_3 & 1 - z_3 \end{vmatrix} \tag{17}$$

Angle a_i is calculated by the scalar product of vectors n_i, and $(0, 0, 1)$

$$a_i = ArcCos(|n_i|/(n_x * 0 + n_y * 0 + n_z * 1)) \tag{18}$$

Then the problem of the optimal arrangement of the model reduces to the search for a matrix of a linear transformation T such that

$$\sum S(T(t_i)) \to MIN(T), \tag{19}$$

such that a $(T(n_i), (0, 0, 1))$ belongs to the interval $(0, 45) \cup (135, 180)$.

Thus, the problem reduces to the search for a rotation matrix, under which the minimum sum of areas of triangles whose normal angles with vertical lie in the intervals (0.45) and (135.180).

Let us consider an example of such an optimization problem using the example of a bracket [5] and [6]. The arrangement of the bracket from the point of view of optimizing the quality of surfaces is intuitively obvious, it is horizontal, it has a good diagram of the distribution of areas along the normal corners and the proportion of areas with poor surface quality is 14%. By poor quality we mean those surfaces whose normal angle with the vertical lies in the intervals (0.45) and (135.180).

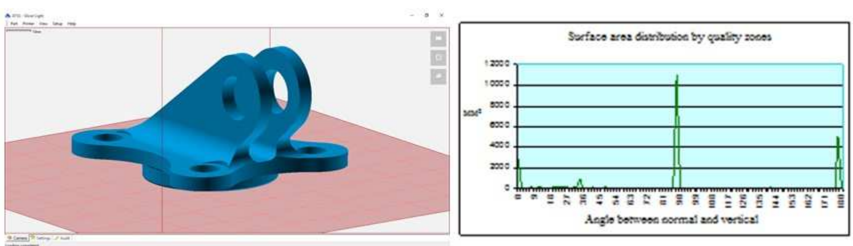

Figure 5: The horizontal arrangement of the bracket and the diagram of the distribution of areas by zone. The proportion of areas in areas of poor quality is 14%

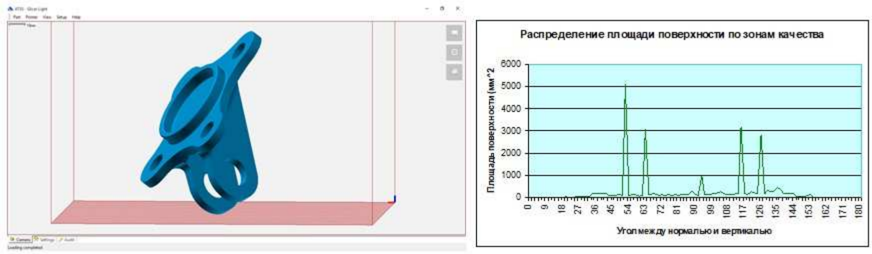

Figure 6: Optimum in terms of the quality of the surfaces of the arrangement of the bracket and the diagram of the distribution of areas by zone. The share of areas in areas of poor quality is 12%

The cosine of the angle between the vectors is calculated by the following formula:

$$\cos\beta = \frac{x_1x_2 + y_1y_2 + z_1z_2}{\sqrt{{x_1}^2 + {y_1}^2 + {z_1}^2} \cdot \sqrt{{x_2}^2 + {y_2}^2 + {z_2}^2}} \tag{20}$$

Nevertheless, having solved the optimization problem, it was possible to find such an intuitively not obvious arrangement of the bracket, in which the share of areas with bad surfaces was reduced to 12%.

Conclusion

Of course, in general, the problem of the correct positioning of the part in the chamber is complex and multicriteria. The location is affected by many factors and much depends on the specific printing technologies, materials used, equipment parameters, etc. However, it is quite possible to implement a software tool, which at the stage of technological preparation told the technologist about the optimal location of the part in terms of the quality of the surface obtained.

Acknowledgment

The work was carried out with the financial support of the state project of the Ministry of Education and Science the project code 2.9219.2017/BCh.

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