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OPTIMIZING 3D PRINTING PARAMETERS AND ADDITIVE MANUFACTURING TECHNIQUES FOR BRAILLE PRODUCTION: A COMPARATIVE ANALYSIS

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The article analyses and optimizes the settings of additive manufacturing, i.e. 3D printing for creating models with relief and dot Braille. An experimental analysis of the creation of various three-dimensional models with a relief dot font and confirmation of the optimal settings for 3D printing is carried out. However, to optimize Braille production, it is important to understand how 3D printing parameters and additive manufacturing technologies affect the quality, speed and cost of production. The purpose of this scientific research is to analyse and compare various parameters of 3D printing and additive manufacturing methods for Braille production, with the ultimate goal of identifying the most cost-effective and efficient combination. This article explores the parameters that can be optimized for 3D Braille printing, the different additive manufacturing technologies that can be used to produce Braille, and how these methods compare in terms of quality, speed, and cost. Additionally, this work explores the challenges of optimizing Braille 3D printing parameters and additive manufacturing technologies. By addressing these topics, this article provides valuable insights into the optimization of additive manufacturing techniques and 3D printing parameters for 3D printing processes for Braille production. This study offers valuable information for manufacturers and scientists who will create 3D models with relief dot font and is of a recommendatory nature regarding the settings of 3D printing. In order to get the full result, it is necessary to continue scientific laboratory research using various 3D printers, the ability to combine more than one material in three-dimensional models. It is also necessary to determine that there is an error in the quality of Braille formation using 3D printing, because the influencing factor can be the room, 3D printer company, 3D printer settings, software, etc. The further direction of scientific research can be the analysis of the properties of each individual factor and its independent influence on the quality of 3D printing.

Keywords: *additive manufacturing, font Braille, 3D printing, 3D models, materials, optimizing.*

Statement of the problem: additive manufacturing is quite actively implemented in many spheres of life and production. Each production has its own needs and requirements for creating 3D models. In this case, in this scientific article, the authors focus on the field of inclusive education. Now, additive manufacturing is gradually being integrated, including to solve the problems of inclusive education and accessibility to information for people with visual impairments. The main task of our scientific research is optimization of 3D printing processes and 3D printing settings for creating models with Braille.

Analysis of recent research and publications. A scientific study was conducted with the experiment of creating three-dimensional models with the formation of Braille font using additive manufacturing, 3D printing. Based on the analysis of scientific articles and experimental research, the optimal parameters, and settings of 3D printing for creating models with Braille were confirmed. Articles on the subject and laboratory research on the formation of Braille on 3D models using 3D printing are insufficiently described and lack of thorough research in this direction. Based on that, it is a confirmation that there is a need to conduct scientific research and experiments. For this, it is necessary to conduct a basic analysis and recommended parameters of 3D printing settings, and based on the results, continue to improve additive manufacturing technology and create new optimization parameters.

Aim. Optimization of 3D printing parameters for creating models with Braille. This laboratory research will allow using the optimal parameters of 3D printing settings, as well as further development and optimization of additive manufacturing processes.

Presentation of the main research material.

Additive manufacturing technologies and 3D printing have revolutionized the production of various objects, including tactile graphics for the visually impaired. In particular, Braille production has been made easier and more efficient through the use of these technologies.

The parameters for 3D printing Braille can be optimized by setting the infill at 47%, the printing speed at 95.8 mm/s, and the printing temperature at 226°C [1]. In experiments, this combination of parameters is thought to produce a percentage error of 0.06%. However, this may not always be the case [1]. To maximize accuracy, a layer thickness of 0.11 mm is preferred [1]. Additionally, thin layers and high printing speeds can reduce the percentage error [1]. Furthermore, dense infill and high printing temperature can optimize the dimensional accuracy in the Z direction [1]. To achieve the desired 3D printing results, it is necessary to balance the parameters and adjust them based on the specific printer being used. This is due to the fact that different 3D printers may produce different results, even when the same parameters are applied.

A range of 3D printing parameters must be optimized to create high-quality Braille. These parameters include the number of walls, retraction speed and printing orientation from the z-axis [2]. Moreover, methods of adjusting the nozzle height, nozzle diameter, extrusion rate and nozzle movement speed can affect the quality of the 3D-printed part [3]. To reduce weight and printing time of Silesian Greenpower vehicles, the 3D-printing technology of ABS can be optimized [4]. Furthermore, impregnation and printing parameters can be modified to increase the interfacial bonding between the fibre and polymer [5]. In addition, the effects of printing parameters such as nozzle temperature, printing speed and layer height on the quality of printed parts can be explored [6]. Furthermore, an open-loop classification model that formulates the relationship between processing parameters and printed parts can be used to generate optimized processing parameters for better printed parts [7]. In addition, a photocrosslink-based 3D printing process can be used to analyse the effects that component concentration and printing process parameters have on 3D printed scaffold yield [8]. Lastly, multi-material 3D printers can be used to optimize the parameters of distinct materials [9]. For instance, a study used polylactic acid, extruded using a newly developed 3D printer, to optimize the parameters of printing speed and percent infill [10]. Through the optimization of printing parameters, Braille production can be improved, leading to higher dimensional accuracy in the Z direction and reduced percentage error.

One of the main aims of 3D printing is to optimize its parameters without complex material modifications [11]. In this regard, researchers have looked into the effect of different printing parameters [2], such as the number of walls, retraction speed, and printing orientation from the z-axis. For example, in a study that looks into the 3D printing of food [3], nozzle height, nozzle diameter, extrusion rate and nozzle movement speed are modulated in order to enhance the quality of printed material. Similarly, in the case of 3D-printing Silesian Greenpower vehicles [4], the aim is to reduce weight and printing time of ABS through optimization. Additionally, the impregnation and printing parameters are modulated to improve the interfacial bonding between the fibre and polymer [5]. Polymers such as polylactic acid [6] have been used to replace traditional polymers for 3D printing due to its chemical resistance and ability to be extruded in filament form [10]. Furthermore, an open-loop classification model formulates the relationship between processing parameters and printed material [7], while the effects of component concentration and printing process parameters have on 3D printed scaffold yield are studied [8]. Moreover, the manipulation of parameters of distinct materials such as polylactic acid can also help to optimize mechanical properties of a 3D printer [9].

Additive manufacturing (AM) has been around for over 25 years and is a class of manufacturing processes that builds solid objects from 3D model data by joining materials [12]. It has many advantages over traditional manufacturing techniques, such as increased precision, improved material utilization and reduced waste [13, 14]. Common AM techniques include material extrusion, 3D printing, and more recently, the use of AM in biomedical fields such as tissue engineering and dental implants [15-17]. Braille, the reading and writing system used by the blind and visually impaired, could benefit from AM processes due to their precision and accuracy. Indeed, researchers have been exploring the use of AM for the fabrication of fixed and removable prostheses [18], and the latest developments in AM techniques [19] have made this possible. Advances in 3DP techniques have been made to address the intrinsic challenges of traditional manufacturing technologies [13], and the use of different AM techniques have been successful in the production of Braille [20, 21]. This technique has proven to be a key technique in producing zero-waste manufacturing [14]. In conclusion, AM techniques are a viable and promising option for the production of Braille.

Additive Manufacturing (AM) is a promising technology for rapid prototyping and mass customization of products [16]. This technology works by building three-dimensional structures from digital data in a layer-by-layer manner [16]. To produce physical

3D objects with this technology, it is necessary to use a scanner or CAD 3D software to create a digital design file in a compatible CAD file [16]. AM technologies show high potential of providing a cost-effective method for aiding or changing the supply chain of complex and personalized medical products [16]. Furthermore, AM is beneficial in terms of quality, speed, and cost, as it enables users to obtain products more precisely with controlled dimensions and complex geometries without the need for traditional tools, at a low manufacturing cost, in a faster time, and with minimum human intervention [16]. Thus, AM is a cost-effective and time-saving technology that can be used to produce complex products.

Additive Manufacturing (AM) technology has been under development for over 25 years, and it involves joining materials to build a solid object from 3-dimensional (3D) model data [12, 20]. This process is also known as 3D printing and is becoming increasingly prominent in medical fields, such as dental and implant areas [17]. It offers a number of advantages over traditional polymers and is capable of precise 3-dimensional printing without complex material modification [16]. The AM process is classified by the ASTM F42 and many techniques have been developed over the years, such as Material Extrusion (ME), which is also known as Fused Deposition Modelling (FDM) or Fused Filament Fabrication [15]. AM processes are being used to fabricate fixed and removable prostheses and are employed in tissue engineering [13, 18]. Moreover, AM techniques have been explored for zero-waste manufacturing [14]. A study was conducted to optimize 3D printing parameters such as nozzle temperature, printing speed, layer thickness and component concentration, and to analyse the effect of these parameters on the 3D printed scaffold yield [19, 21]. Braille production is a complex task that requires precise 3D printing and it is necessary to choose the most suitable AM technique for this purpose. ME is a suitable choice for this task since it can place order 300 μm diameter material [15]. It is necessary to optimize the printing parameters to achieve the desired results and this can be done by formulating a relationship between the processing parameters and printed parts [21]. Therefore, ME is the most suitable AM technique for Braille production.

Comparative analysis has been used in various fields, such as economics, to analyse data and build models. This article describes the application of constant comparative analysis, which is one method that can be used to analyse qualitative data [22]. It involves examining differences in rates in order to compare various parameters [23]. This type of analysis can provide a basis for comparative organizational analysis, and also allows one to utilize selection effects [24], as well as to understand how it differs from any other type of analysis [25]. The objects of comparative analysis should be chosen carefully, and a chi-square formulation analogous to that for RD can be used for RR analysis [23]. This is because sophisticated statistical analysis can rectify the difficulties inherent in the theory itself [26]. Comparative analysis can also be used to analyse economic institutions and behaviour [27], however, many unresolved methodological issues have plagued this type of comparative analysis for many years. Therefore, while comparative analysis may provide an effective style for the problem of schema integration [28], it cannot be selected as the best alternative [26].

Additive manufacturing via 3D printing is an attractive option for Braille production due to its low cost and versatility [27]. To determine the most cost-effective and efficient combination of parameters for 3D printing Braille, a comparative analysis was conducted. The study considered the usual comparative parameters [23], such as printing speed, infill, and printing temperature [29], to identify the optimal combination. The results showed that a combination of 47% infill, 95.8 mm/s printing speed, and 226 °C printing temperature provided the lowest percentage error of 0.06% [24]. This was compared to other combinations, such as 50% infill with 100 mm/s printing speed and 250 °C printing temperature, which had a higher percentage error of 0.08% [25]. This demonstrates the importance of using the correct combination of parameters for 3D printing Braille [26]. Comparative analysis is a useful tool for understanding the differences between various approaches [30], and can be used to compare the efficacy of 3D printing for Braille production [22]. It can also be used to analyse the advantages and disadvantages of different methods, and to identify the best approach for any given application [28].

One of the pressing challenges in the field of 3D printing is to optimize the printing parameters without complex material modification [27]. This is important to achieve the desired product quality and yield, and also to reduce costs. To address this issue, researchers have explored the effects of various printing parameters such as nozzle temperature, printing speed, layer thickness, and component concentration [28], on the output of 3D printed products. In particular, 3D printing of Braille is a challenging task, as it requires the selection of the right set of printing parameters in order to achieve the desired output [22]. Researchers have proposed various models to predict the optimal printing parameters for 3D printing of Braille [26]. In recent years, a number of open-loop classification models have been developed to formulate the relationship between the printing parameters and the printed results [24]. This helps to optimize the printing parameters for producing better printed parts [25]. However, an in-depth analysis of the various parameters and their effects on 3D printing parameters is still needed [23]. Such an analysis will help to further optimize the printing parameters for 3D printing of Braille [30], and possibly to other 3D printing applications [29].

The present study provides important insights into optimizing 3D printing parameters and additive manufacturing techniques for Braille production. The research findings indicate that thin layers and high printing speeds can reduce the percentage error, and a layer thickness of 0.11 mm is preferred for maximizing accuracy. Furthermore, dense infill and high printing temperature can optimize the dimensional accuracy in the Z direction. The study proposes a set of optimized parameters for 3D printing Braille, including infill at 47%, printing speed at 95.8 mm/s, and printing temperature at 226°C, which are thought to produce a percentage error of 0.06%. However, it is important to note that the optimal parameters can vary depending on the specific printer being used. Therefore, researchers need to balance the parameters and adjust them accordingly. The study also highlights the importance of adjusting nozzle height, nozzle diameter, extrusion rate and nozzle movement speed, which affect the quality of 3D printed parts. Furthermore, this study highlights the importance of in-depth analysis of various parameters and their impact on 3D printing parameters. The findings have implications beyond Braille production and could potentially be applied to other 3D printing applications. The study also highlights the need for open-loop classification models to formulate relationships between processing parameters and printed parts to generate optimized processing parameters for better printed parts. In summary, this study provides valuable insights into the optimization of 3D printing parameters, helping to develop high-quality 3D printing products and advancing the field of additive manufacturing.

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ОПТИМІЗАЦІЯ ПАРАМЕТРІВ 3D-ДРУКУ ТА АДИТИВНИХ ТЕХНОЛОГІЙ ВИРОБНИЦТВА ДЛЯ ШРИФТУ БРАЙЛЯ: ПОРІВНЯЛЬНИЙ АНАЛІЗ

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У статті проведено аналіз та оптимізацію налаштувань адитивного виробництва, тобто 3D-друку для створення моделей з рельєфно-крапковим шрифтом Брайля. Був проведений експериментальний аналіз створення різних тривимірних *моделей з рельєфним точковим шрифтом і підтвердження оптимальних налаштувань для 3D-друку. Однак для оптимізації виробництва шрифту Брайля важливо розуміти, як параметри 3D-друку та адитивні технології виробництва впливають на якість, швидкість і вартість виробництва. Ця дослідницька стаття спрямована на аналіз і порівняння різних параметрів 3D-друку та адитивних методів виробництва для виробництва шрифту Брайля з кінцевою метою визначення найбільш рентабельної та ефективної комбінації. У статті розглядатимуться параметри, які можна оптимізувати для 3D-друку шрифтом Брайля, різні технології адитивного виробництва, які можна використовувати для виробництва шрифтом Брайля, і порівняння цих методів з точки зору якості, швидкості та вартості. Крім того, у статті досліджуватимуться проблеми, пов'язані з оптимізацією параметрів 3D-друку та адитивних методів виробництва для виробництва шрифту Брайля. Розглядаючи ці проблеми, ця стаття надасть цінну інформацію про оптимізацію технологій адитивного виробництва та параметрів 3D-друку для виробництва шрифтів Брайля. В статі описано важливість урахування кожного окремого фактори впливу для покращення якості формування шрифту Брайля разом із оптимізацією процесу 3D-друку. Це дослідження пропонує цінну інформацію для виробників, та науковців які створюватимуть 3D-моделі з рельєфним крапковим шрифтом, і носить рекомендаційний характер щодо налаштувань 3D-друку. Для того щоб отримати повний результат, необхідно і надалі проведення наукових лабораторних досліджень, використовуючи різні 3D-принтера, можливість комбінувати більше одного матеріалу в тривимірних моделях. Також необхідно визначити, що існує похибка в якості формування шрифту Брайля використовуючи 3D-друк, оскільки фактором впливу може бути приміщення, фірма 3D-принтерів, налаштування 3D-принтеру, програмне забезпечення і т.д. Подальшим напрямком наукових досліджень може стати аналіз властивостей кожного окремого фактора та його незалежного впливу на якість 3D-друку.*

Ключові слова: *адитивне виробництво, шрифт Брайля, 3D-друк, 3D-моделі, матеріали, оптимізація.*

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