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Analysis of the Possibilities of Applying Artificial Intelligence to Modeling and 3D Printing of Drone Elements from Polymeric Materials

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Abstract: The subject of the article is to present the possibilities of using artificial intelligence for modeling and 3D printing of drone structural elements from polymer materials. The traditional three-dimensional modeling process based on 3D-CAD systems and the modeling method using artificial intelligence algorithms were analyzed. The project implementation time, design assumptions and accuracy of models obtained using both methods of creating numerical models were compared. Test models produced by 3D printing from polymer materials based on previously prepared numerical data were also presented.

Keywords: Artificial Intelligence (AI); drone; polymer materials; 3D modelling; 3D printing

1 INTRODUCTION

The term "drone" is a commonly accepted term for an unmanned aerial vehicle (UAV) or an unmanned aircraft system (UAS). The above names refer to an aircraft that does not have a pilot, crew or passengers on board [1]. Objects defined in this way can be remotely controlled or constitute autonomous systems. The term drone appeared in the 1920s and 1930s in military technology in solutions for which the presence of a human on board was unnecessary or dangerous. The first solutions concerned target aircraft intended for shooting practice. Currently, with the development of technology, the use of drones has expanded to many non-military areas. Drones are widely used in photography, broadly understood monitoring (agriculture, forest areas, power lines, etc.), inspection and control, and even product delivery. The commonness and availability of modern solutions means that they have even become elements of entertainment [2]. Drone races can serve as an example. Depending on the type of mission performed, drones can be fixed-wing or rotary-wing aircraft [5]. The wide use of unmanned systems has become possible thanks to the miniaturization of electronics and the introduction of modern polymer construction materials. Composites consisting of a polymer matrix and reinforcement in the form of glass, carbon or aramid fibers enable the serial production of elements with favorable stiffness and strength parameters at low weight [14]. Another direction of development concerns the practically unlimited possibilities of shaping structural elements using additive manufacturing methods [11].

Unmanned aerial vehicles are currently an important element of transport and logistics in many sectors of the economy, and they play a particularly important role in the area of offensive and defensive military technologies [15]. The production of drones can be based on the use of serial components, but prototype solutions manufactured using 3D printing can also be successfully used [3]. In such a case, special-purpose drones with a structure dedicated to specific tasks can be designed and built [4]. Additive technologies allow for a fairly large degree of freedom in shaping the drone's structure, and various methods of optimizing this structure can also be used in terms of its strength and mass [6]. The classic approach to designing a structure takes into account its strength properties, which are the basis for developing a model and prototype [7]. Additive technologies allow for the production of complex geometric shapes and structures, which is why topological optimization can be used in the design process [13]. A separate design issue is the possibility of using programs using artificial intelligence algorithms for three-dimensional modeling of objects. Such programs have recently experienced dynamic development, especially in the area of modeling objects for which maintaining specific dimensions or manufacturing tolerances is not important, such as: building models, human and animal figures, etc. [8].

When analyzing the issue of potential application of AI in the process of 3D modeling and printing, various areas can be distinguished. One of them is the selection of materials for printing [12, 13], in order to optimize the matching of material properties to the needs of the application and working conditions of a given drone. Such an approach can take into account various structural, environmental or mechanical requirements and at the same time correlate them with the mechanical properties of a wide range of polymers. Considering the reduction of the time of the entire design and manufacturing process, and at the same time reducing the costs associated with defective components, prediction and control of print quality play a very important role [9]. Especially in this area, AI can control the course of the 3D printing process in real time. For this purpose, both AI models identifying anomalies and deformations in the structure of the printed object using advanced image analysis, as well as AI tools processing sensory data from the environment and the printed object (e.g. temperature, humidity, growth rate of the printed object, etc.) can be used [10]. Another area of AI application is simulations. Trained models based on theoretical, catalog, experimental and simulation data can improve the process of optimizing strength and aerodynamic properties. In such a case, Big Data can support the prediction of the behavior of the developed structures in various operating conditions. As can be seen, the presented issue is very broad [11]. Therefore, this work focuses on the use of software based on artificial intelligence algorithms, which allows for modeling objects based on entered data in the form of descriptive (text) or raster images (e.g. photos or screenshots). Entering data in text form is limited by the number of characters, which in turn are responsible for the detailing of the data. This detail does not always translate into the mapping of these details in the geometry of the developed model and geometric accuracy. A very detailed description of the object can introduce interference in the model generation process in the form of additional elements that may not be geometrically and programmatically consistent with the assumptions of the object's geometry. Taking the above into account, the issue of entering input data as an object description may constitute a separate research issue.

2 DESIGNING DRONE ELEMENTS USING 3D-CAD MODELLING

Modeling objects using 3D-CAD software allows for the creation of almost any three-dimensional objects, which can then be manufactured using production systems based on numerically controlled machining. In the case of structural elements manufactured using 3D printing used to build drones using multi-rotor drives, the design of the structure must take into account the structure and dimensions of individual elements such as the engine, propeller, control system or batteries. An example of a drone shown in Figure 1 manufactured using 3D printing can be an unmanned ship made as part of drone construction research at the Department of Machine Design of the Rzeszów University of Technology and the implementation of diploma theses [5].

Figure 1 Drone prototype made using 3D printing [5]

The dimensions and geometry of the drone must be adapted to the capabilities of the 3D printer. For 3D printers with a large workspace, drone bodies can be manufactured in their entirety, without the need to divide them into component parts.

The drone prototype shown in Fig. 1 was made of components, the housing of the control system and battery, and the arms mounting the engines. All the elements were connected to each other using screws. The use of a structure consisting of several elements was dictated by the use of a 3D printer for production with a workspace that does not allow for printing the entire body. The use of printers with a larger workspace allows for modeling the body elements as a whole. An example of such an approach is the model of the drone body made using 3D-CAD CATIA software (Fig. 2).

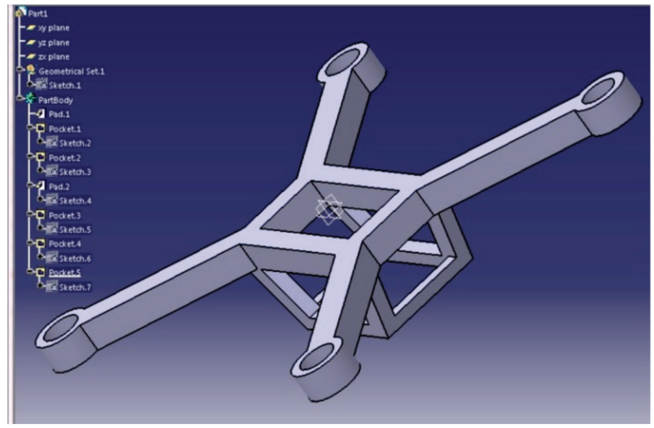

Figure 2 3D-CAD model of the drone body made in CATIA

Rotor drones do not have to meet special aerodynamic requirements, because the lift force and flight trajectory control are implemented using the engine control system. Taking this into account, the geometry of such a drone can be relatively simple, it can be made in the process of solid modeling and does not require the use of special methods of surface modeling, which in most cases takes more time than solid modeling. To make a drone body using the 3D printing method, data must be prepared in a form readable by the printer software, e.g. in STL format (Fig. 3). Geometric data in this form is generated based on the solid model.

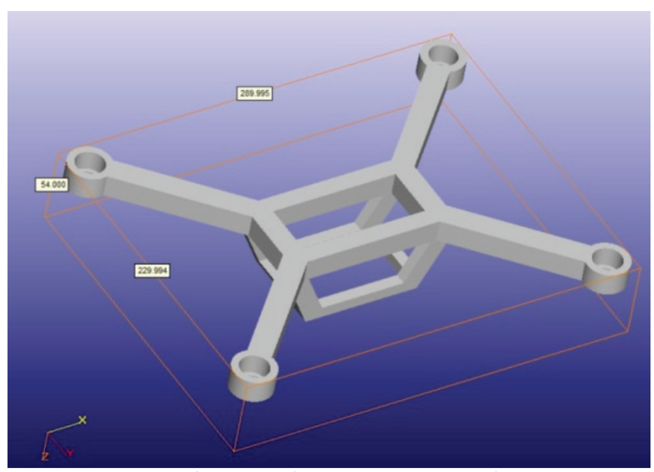

Figure 3 STL model of the drone body made in CATIA

Analyzing the complexity of the structure and the applied 3D-CAD modeling procedures, the time of modeling and data preparation for the drone body shown in Figs. 2 and 3 was recorded, which amounted to 44 minutes in total. The presented numerical model was used to make a 3D print of the body from PLA polymer material using MEX process, FFF technology (Fig. 4).

Figure 4 A prototype of a drone structure made on the basis of a 3D-CAD model using the 3D printing method

3D-CAD modeling allows for taking into account a number of design assumptions, while the accuracy of the numerical model is high, in most engineering programs it is within the value of 0.001 mm, which should be considered sufficient both in the use of 3D printing technology and machining on CNC machines. An important feature of 3D-CAD modeling is the ability to quickly modify the drone's structure in the output file area and adapt the structure to individual applications and operational activities, e.g. transporting unusual loads.

3 DESIGNING DRONE ELEMENTS USING ARTIFICIAL INTELLIGENCE-BASED PROCEDURES

As part of the conducted research, commercially available applications for modeling three-dimensional objects based on artificial intelligence algorithms Meshy AI 3D Model Generator were used. Two methods of entering data as information about the designed model were selected, i.e. the descriptive (text) method and the method of generating a model based on a photograph of an existing object. In the case of the descriptive method, several variants of the description were introduced with varying degrees of detail and type of language. For modeling based on the analysis of photographs, a photo of a four-engine drone previously developed at the Rzeszow University of Technology, shown in Fig. 1, was used. The photo in JPG format was loaded into the software based on AI algorithms and the process of generating a 3D model was started. After about 2 minutes, a three-dimensional numerical model was generated, shown in Figure 5. This drawing, which is a screenshot from the program, shows some similarities to the model saved on a digital photograph. The software used allows for the generation of many versions of models, however, due to the volume of the article, the one closest to the original was selected. The developed numerical model can be saved in the form of files in various formats, e.g. STL, which allows for 3D printing (Fig. 6).

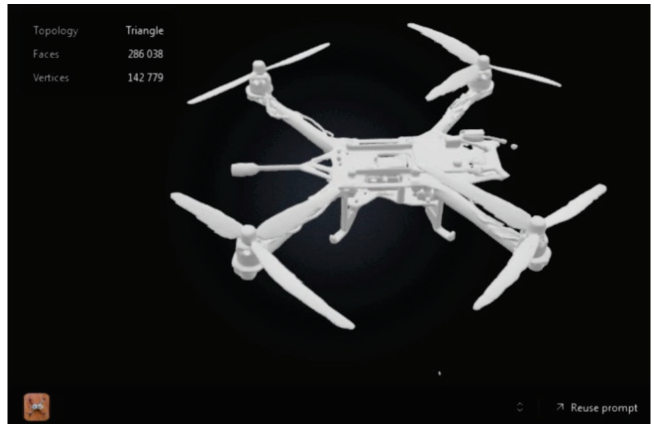

Figure 5 3D drone model generated using AI based on photography

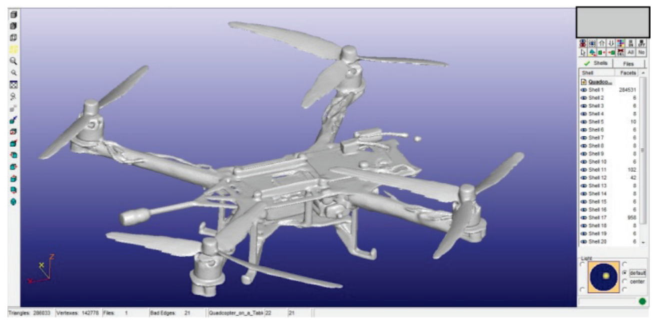

Figure 6 STL model generated using AI based on photography

Analyzing the STL model shown in Figure 6, it can be seen that it consists of several dozen objects generated as open and closed triangle meshes. From the point of view of the manufacturing process based on 3D printing, making a physical prototype requires the use of closed mesh models. Fragments of meshes are most often read by the software controlling the 3D printer as file defects that prevent the 3D printing process from starting. For this reason, the physical prototype shown in Figure 6 of the STL model was not made. In order to develop the drone construction model, the descriptive method was also used, for which the following text was entered into the program window: "supporting structure of a quadrocopter drone with the attachment of four electric motors, battery and control system attachment". The program generated a model of a drone equipped with a drive and control system, although the description content presented the task of making a model of the supporting structure itself (Fig. 7). Additionally, one can see irregularities in the model geometry or model defects in the form of propeller blades with random geometry. Considering the disruptions of the developed geometry, in this case, it was decided not to make a 3D print for this model. The algorithm, based on its own assessment, determined the importance of individual words that make up the model description, and the presented model shows that it used the key word quadrocopter to describe a four-engine drone. The generation time of the model shown in the figure did not exceed 2 minutes.

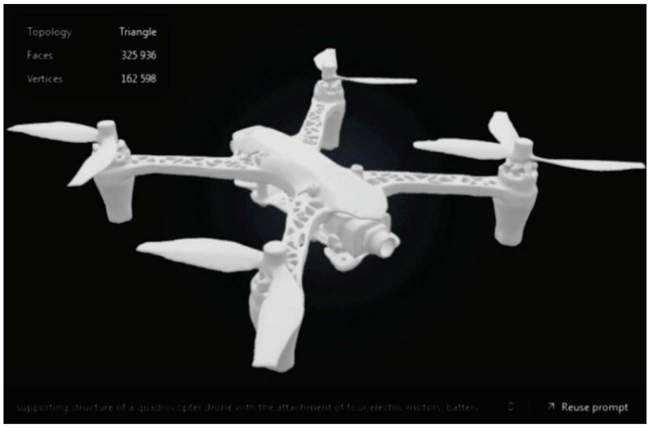

Figure 7 3D model of a drone generated using AI based on text description

An additional attempt was made to modify the data in terms of shortening the text description in the form of: "supporting structure of a quadrocopter drone". The view of this variant of the model generated using artificial intelligence is presented in Fig. 8.

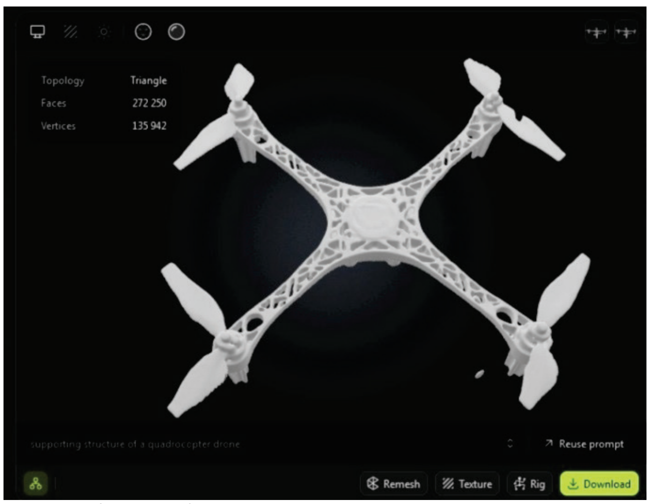

Figure 8 3D model of the drone generated using AI based on a shortened text description

This model was then saved in STL format (Fig. 9) in order to test the production of a physical prototype using 3D printing.

Figure 9 STL model generated using AI based on text description

On this basis, a 3D print was made from PLA polymer material using the MEX process and FFF technology. The prototype view is shown in Fig. 10.

Figure 10 3D drone print made from AI-generated data based on text description

The presented model has an irregular shape, which is unacceptable for technical objects. The automatic modeling process introduced design assumptions aimed at reducing the model's mass by using a skeleton structure. However, discontinuities in this structure are visible, which will negatively affect its mechanical, static and fatigue strength. Additionally, the possibility of changing the language from English to Polish was analyzed and the description of the object was formulated as an unmanned aerial vehicle in Polish: "bezzałogowy statek powietrzny". Based on such a description, the four-engine drone shown in Fig. 11 was generated. It should be noted here that the text did not assume the number of engines used, but the program assumed that the model would have four engines, perhaps it was a kind of continuation of previous activities, which assumed the number of engines in the description.

Figure 11 STL model generated using AI based on text description in Polish

The generated 3D model was saved as an STL file for 3D printing purposes and, as can be seen in Fig. 12, four geometrically flawless mesh objects appeared in the dialog box on the right (shell 1 – Shell 4), which could be used directly to make a prototype using the 3D printing method.

Figure 12 STL model generated using AI based on text description in Polish

Fig. 13 shows a prototype made as before in the MEX additive process, using FFF technology from PLA material.

Figure 13 3D drone print generated using AI based on text description in Polish

4 CONCLUSIONS

As part of the work carried out, a total of several models were generated using software based on artificial intelligence algorithms Meshy AI 3D Model Generator. The time of generating subsequent models based on the AI algorithm was similar and did not exceed two minutes on average. On the other hand, the time of making the model using 3D-CAD software in the traditional way took about 45 minutes. Comparing only the time values, it can be seen that the AI algorithm generates a three-dimensional model very quickly. However, attention should be paid to the quality of the obtained geometric data from the engineering point of view. In general, the models generated by the AI algorithm meet the assumptions entered into the program as descriptive or raster input data. Objects were generated that geometrically meet the assumptions of its description of a four-engine drone. Models generated using AI are burdened with a large amount of geometry interference. Models generated using AI did not meet the technical assumptions of the engineering project, both in terms of the accuracy of the model execution and any definition of dimensions, especially in relation to the assembly of the drive system or control. Additionally, the software using AI allows the geometric data of models to be saved in formats that are difficult to edit and introduce design changes. Ultimately, it may translate into a significant extension of the production time of a 3D model, often exceeding the modeling time using 3D-CAD software.

An engineering project is implemented based on an assumed methodology defining the purpose of the object, strength, materials used, geometric accuracy and method of execution. Each of these stages is controlled by the designer. In the case of using an AI algorithm for design, the software accepts the description as input data without the possibility of using feedback. It is also difficult to determine in the case of using a descriptive algorithm which words the algorithm will consider important from the point of view of the project and which will be treated as secondary. This is an important issue in the case of using AI for design, but it goes beyond the scope of this study.

An important criterion for using the method of modeling three-dimensional objects is their purpose. If we intend to develop a preliminary conceptual model, it is reasonable to use software that generates geometry using AI algorithms. In the case of work on the design of an engineering structure and a functional prototype, classic 3D-CAD modeling methods should be used, which allow the creation of a precise numerical model intended for production using the 3D printing method or other technologies based on numerical data.

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