MODELLING THREE-DIMENSIONAL NUMERICAL OBJECTS USING SOFTWARE BASED ON AI ALGORITHMS - CREATIVE AND INTELLECTUAL RIGHTS

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SUMMARY:1. Introduction; 2. Three-dimensional numerical (digital) models; 3. Creative modelling using 3D-CAD systems; 4. Reproducible modelling based on reverse engineering; 5. Object modelling using software based on AI algorithms; 6.Legal aspects of numerical modelling; 7. Conclusions for Further Research

Abstract:The issue of three-dimensional numerical modelling is becoming increasingly popular. This raises various questions, not only about the scope of its use, but also about the admissibility of this type of activity in connection with possible legal restrictions. Additional doubts have arisen in connection with the possible use of artificial intelligence for this type of modelling. The authors attempt to indicate where the underlying doubts lie and outline possible elements for future discussion.

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1. Introduction

The creation of numerical models, popular and widely used recently in many projects, is a broad issue relating to both technical and legal aspects. Numerical modelling, from a technical point of view, consists of specific procedures and sequences performed in a specific order to produce a two- or three-dimensional model, using a computer programme operated by a designer-creator. In recent times, however, artificial intelligence has entered into such traditional modelling, which is expected to introduce a new quality.

In the modelling process, especially using AI, a number of legal aspects may arise related to, among other things, the area of intellectual property rights, which may indirectly lead to the possibility of marketing the developed model commercially in a specific digital or physical form. The gaming industry or virtual reality have shifted legal issues into the digital area as well, which now poses a significant challenge, no longer just a technological one[5]. Among other things, questions arise as to how to effectively protect the rights to a numerically produced object, both in the layout of the circulation, the control of the data, as well as the appropriate technical means to mark the authorship of a given numerical object. Additional doubts are added by the fact that the market for software for creating images or numerical models is currently shifting from a system of installing perpetual licences on a specific device to enable offline operation and moving towards the purchase of temporary licences for online operation, as if to force greater control over the models created[6].

The purpose of this article is to provide an overview of the development of numerical models, to indicate the related role of artificial intelligence and to outline the legal uncertainties which, against this background, appear to be an important factor in determining the concrete use of the technology. The authors do not pretend, however, to indicate an exhaustive concept for resolving the doubts that arise. Instead, they aim to signal the need for further research in this area and the need for a multifaceted view of the technology and the law

2. Three-dimensional numerical (digital) models

[5]J. Schell 2019, The Art of Game Design, A Book of Lenses, Taylor & Francis Ltd, 2019

[6]A. Paszkiewicz et al., Application of cyber-physical systems for additive manufacturing of polymer products, POLIMERY 2024, 69, no 11-12, pp. 659-664

It should be pointed out that three-dimensional numerical models have a wide range of applications, from the visualisation of objects in art, advertising, architecture or technology, in the area of simulation and computer games, or in virtual and augmented reality. One could venture to say that the virtualisation of objects is beginning to affect most areas of our lives. Modern production systems are based on digital documentation, in which three-dimensional numerical models are made using 3D-CAD modelling[7] . This type of approach is used both in the creation of cyber-physical models used in engineering, aerospace automotive, etc. and in industries based mostly on digital objects, e.g. computer games[8].

Two groups of this type of modelling can be generally distinguished: (1) a creative model, i.e. one that is made directly (or indirectly) by an engineer, artist and (2) a reproducible model, i.e. one that is made by a machine operator based on existing physical objects, two-dimensional paper or digital documentation

The shortest path to obtaining a 3D-CAD model is direct modelling in a CAD environment without the use of preliminary or intermediate steps. Large projects requiring prototyping (e.g. car bodies) or artistic objects can be made from 3D scans, which form the basis for the numerical model, and scanning is one of the next steps in the iterative process necessary to produce a visual prototype.

Creative numerical models can be made as so-called programmable models using automated software routines that create a model after specifying characteristic data for selected groups of objects, e.g. a gear wheel or a coupling. Another way is to create objects based on topological optimisation, a type of modelling based on computational models using the finite element method. The 3D-CAD model provides a nominal benchmark for the implementation of tests, e.g. using the finite element method (FEM) analysis or kinematic simulations[9].

Numerical models as reconstruction models can be created on the basis of existing technical documentation such as a technical drawing or sketch. There are software procedures to convert two-dimensional projections into a three-dimensional model with some accuracy. An interesting example of creating digital models is also the digitization of people and things, which can be realized, among other things, for marketing purposes, for

[7] 3D-CAD (Computer Aided Design) - a group of tools that enable the development of a digital three-dimensional model.

[8]T. Akenine-Moller et al., Real-Time Rendering, Taylor & Francis Ltd, 2018

[9]D. Vuka Sinovic, Advanced CAD Modeling, Explicit, Parametric, Free-Form CAD and Re-engineering, Springer Nature Switzerland AG, 2018 2018

computer games or for virtual reality. A separate issue is the making of medical models used in the treatment process, rehabilitation for the manufacture of implants or surgical templates. Data conversion is one of the ways of creating numerical models, in which case the data may come from various sources as incomplete, defective or saved in formats that are difficult to process into a form that can be used as a commercial numerical model or to produce a physical product. It is also worth mentioning at this point the so-called reverse engineering, which is the process of examining a product to determine exactly how it works and how it was made, being usually conducted to gain the information necessary to construct an equivalent[10].

This can be illustrated as follows (Figure 1):

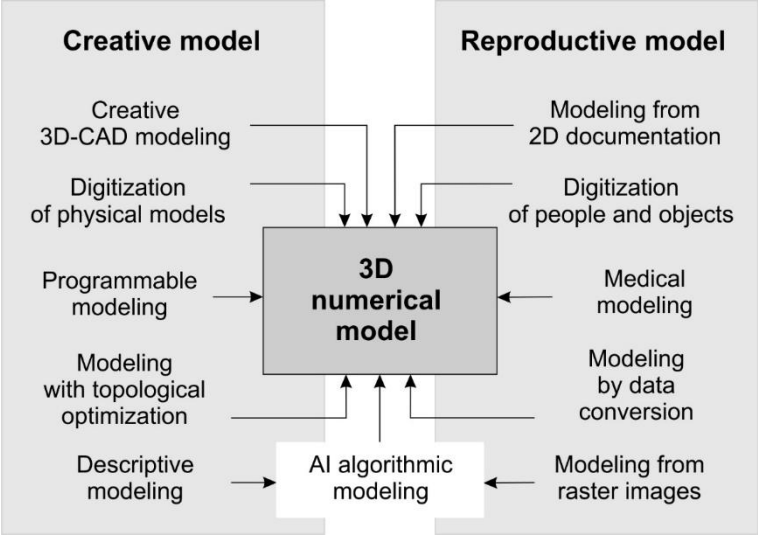

Figure 1. A breakdown of how three-dimensional numerical models are created[11]

3. Creative modeling using 3D-CAD systems

3D modeling enables, among other things, the creation of new geometry. Such a process is an authoring process In the process of modeling an object, different sequences can be used leading to the same model, in which case a certain sequence of commands by

[10]G. Budzik, K. Tomaszewski K., A. Soboń, Opportunities for the Application of 3D Printing in the Critical Infrastructure System. Energies. 2022; 15(5):16562024, https://doi.org/10.3390/en15051656

[11] Figure 1 shows a breakdown of how numerical modelling of three-dimensional objects can be carried out using different procedures. The diagram also shows an algorithmic modelling method using artificial intelligence, where the input data can be raster images or textual descriptions. In this case, the description of the object we plan to model can be considered as the input. In the case of input data in the form of a raster image, it may be a photograph of an existing object for which copyright is specified which can create many problems regarding the legal status of these models.

the modeler the CAD software can be regarded as an authoring process. This can be illustrated by the example of the simplified model of the 8mm hexagon socket shown below (in Figure 2):

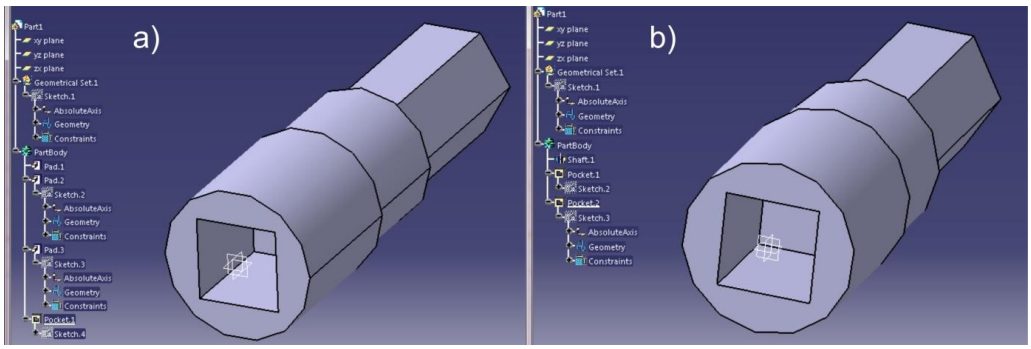

Figure2. [12]

In 3D-CAD modelling programmes, the structure tree is a very important element in the creation of the original model and when making modifications due to technological changes or product upgrades. Please note that the structure tree can only be edited by the same programme and in the same version, possibly in a higher version of this programme. 3D-CAD software enables saving data in universal formats such as STEP, IGS or STL, but these formats describe only the geometry of the solid and it is not possible to edit the structure of the model creation. Meanwhile, it is only possible to save full model information in a format specific to this software. Other fixation of the model (in the universal format) usually leads to the impossibility of further editing of this model and, for example, developing the design. In modelling practice, this may be due to (such a universal saving), among other things, the availability of the specific 3D-CAD software (lack of an appropriate licence).

4. Reproducible modelling based on reverse engineering

Reverse engineering in general is a process that has been known for many centuries, ever since man made the first tools and learned to use them, when there was a desire for other people to own tools, observe their uses and designs and ways of using them. In general, one type of reverse engineering is the copying of processes and objects, whether in archival terms or out of a desire to have the same product (e.g. a work of art).

[12] 3D-CAD model of the hexagon socket made using different command sequences according to the structure tree: a) extraction of the three sketches (circular and hexagonal) and indentation of the square sketch, b) rotation of the cylindrical sketch and indentation of the hexagonal profile and indentation of the square sketch

Reverse engineering (reconstruction engineering) consists of recreating an existing physical object using numerical tools and manufacturing technologies. Digitalisation processes based on three-dimensional scanning using various data processing technologies are used, either on the basis of surface point measurements of the existing object, in the case of surface scanning, or on the basis of volumetric data in the process of computed tomography or magnetic resonance imaging. The reverse engineering process should be viewed multidimensionally, not only in terms of the geometry of the object itself and its transformation into a numerical model. The reconstruction of an object can range from the need to make a faithful copy of the object, a geometric copy without preserving the functional or material properties, and a base reconstruction that can be used to make repairs, technical and archaeological or scientific aids tools. Here, for example, we can use tools to reconstruct archaeological objects in order to analyse past civilisationsor their way of life, in terms not only of daily life but also of the technologies used. The use of such a process may be necessary, for example, when reconstructing a historical object that has been partially or completely destroyed, due to the passage of time or unfortunate events.

Numerical reconstruction of objects is also widely used in medicine, starting with diagnosis itself, which involves analysing 3D images from CT scans or MRIs. This type of data makes it possible to determine a patient's health status, determine the possibility of disease or plan the surgical and treatment process. Currently, this type of data can, among other things, be used by artificial intelligence. Thus, on the one hand, there is the issue of the development of science and medicine based on the accumulation of knowledge about disease cases and finding the best path of treatment, while on the other hand, we are dealing with sensitive data. This type of data can not only provide a picture of a person's current state of health, it can, in a sense, provide information on the cause of disease changes relating to, for example, a person's lifestyle, resulting in a very broad analysis of the person in question.

Object reconstruction based on data conversion represents a certain generalisation of object creation based on different formats and forms of numerical image. The data can come from different sources such as a coordinate measuring machine in the form of a set of points, from photographs of objects from different sides for the photogrammetry process, volumetric cross-sections of an object from computed tomography or from large scale geological scanners and sonar. With this approach to reconstruction, it is necessary to convert the raw data into spatial grids that describe the geometry of the object under analysis.

The restorative modelling path in most cases requires consideration of the legal status of the original object and the legal possibilities of processing and subsequent use of the data

created in the digitisation process - reproduction of this object. In the case of historic objects, the ownership of the object, the ownership of the copyright should be taken into account, perhaps there are cultural heritage assets whose reconstruction scientific research or teaching processes have their justification and are a certain element of the legal status.

5. Object modelling using software based on AI algorithms

A current major issue concerning the modelling of 3D objects is the use of software based on artificial intelligence algorithms, which has recently been gaining in importance. Indeed, there is no doubt that artificial intelligence is an increasingly common phenomenon in various areas of life, and as a result, it has also appeared in the field of numerical modelling discussed here[13]. In this case, the modelling process is limited to providing a descriptive object in text form or loading a raster file of the object as an image or screenshot. It is worth referring here to the type of object, e.g. whether it is a technical object or a human figure (historical or fantasy). In the case of technical objects, it is important to determine the appropriate dimensional and shape accuracy required for the co-operation of the elements in the assembly. In the case of characters, e.g. for computer games or conceptual models for virtual reality, the dimensional accuracy relating to the production of physical products is secondary; more important are the parameters relating to the object's screen resolution and ability to move during play.

Taking this into account, the geometrical parameters of an object in relation to a 3D numerical model are important, regardless of whether the model will be used exclusively in a software environment or will be used as a model for making a physical model. This raises the questions of what accuracy and precision of representation can be achieved using software based on AI algorithms, and how detailed an object can (and should) be described in order to achieve the assumed accuracy and precision . [14]

As an example of modelling using an AI-based algorithm, the gear wheel modelling performed for this thesis can be used. The basis for the model was a prototype and the model was presented as a raster file saved in JPG format as a snapshot of the gear wheel model (Figure 3). Originally, the gear wheel was manufactured as part of research work carried out

[13]F. Da Silva Veiga, M., Zalucki, Legal Aspects of Artificial Intelligence Application in Medicine and Healthcare, Instituto Iberoamericano de Estudos Jurídicos - IBEROJUR, Portugal 2023

[14] In the description above, the concepts of dimensional accuracy and mapping precision are specifically separated, as these issues are often a separate issue when it comes to numerical models of three-dimensional objects and the way models are made, e.g. by 3D printing.

at the Department of Mechanical Engineering, Rzeszów University of Technology, using the Powder Bed Fusion process and Direct Metal Laser Sintering technology from EOS, which was subjected to finishing (Figure 3a). The gear wheel was made based on a 3D-CAD model converted to STL format, the view of which is shown in Figure 3b.

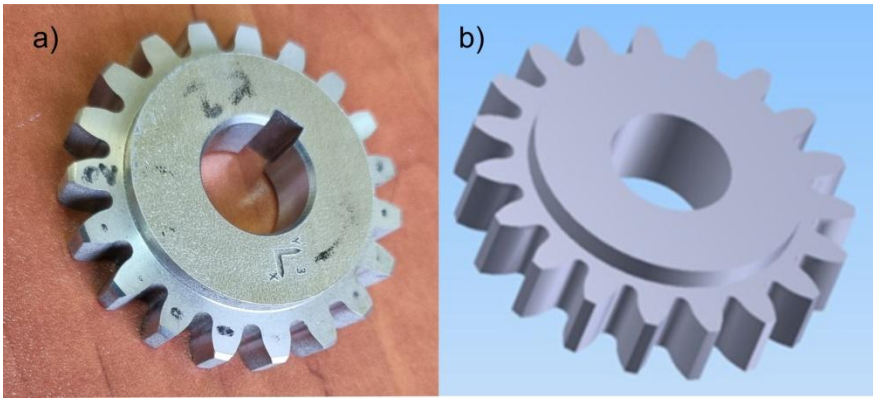

Figure3. [15]

Meshy AI 3D Model Generator software in a test version was used in the research process. The software allows numerical models of 3D objects to be made at based on a text description or from a raster image derived from a photograph, 2D scan or screenshot. The process of modelling a gear wheel by entering the data as a view is shown in Figure 4.

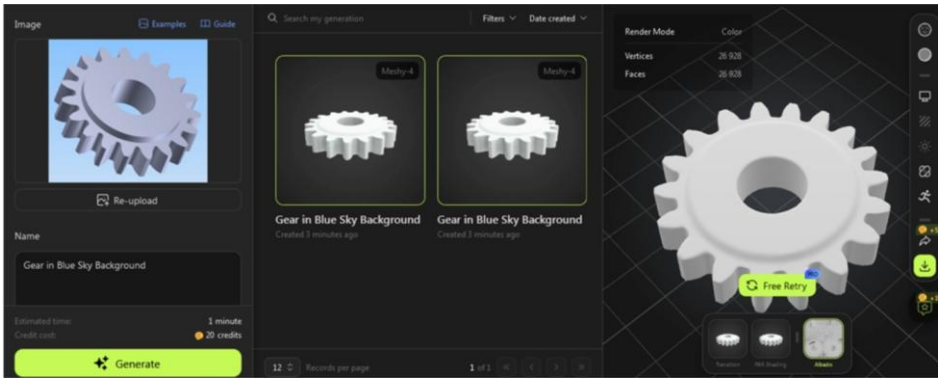

Figure4[16]

The software allows the generation of three-dimensional models in various formats such as OBJ, FBX, USDZ, GLB, BLEND and STL. The OBJ format allows the spatial model to be described in terms of surface geometry and to indicate the colour and texture information of the object. Files in FBX format can be designed and modified in various modelling applications such as Maya, 3ds Max and Blender. They typically contain mesh,

[15] View of the gear wheel used in the tests: a) prototype gear wheel, b) raster image of the gear wheel

[16] View of the program window during gear wheel model generation

material, texture and skeletal animation data. The USDZ form allows a single file to be saved, containing information about the mesh data, binary data and textures of the model. An object saved in STL format represents geometry in the form of a surface triangle mesh. It is used for 3D printing and saving data after the 3D scanning process. These models can be intended for further software processing or directly for 3D printing. However, it should be noted that software processing of models generated using AI algorithms is difficult and requires the use of specialised software to process data stored in STL format. Figure 5 shows a view of an STL model of a gear wheel opened in a 3D printer software and a physical prototype made using a 3D printer with polymer material.

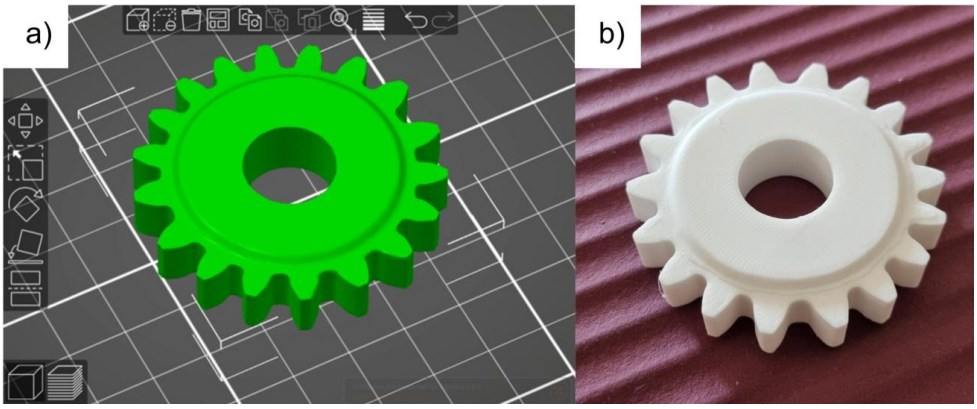

Figure 5 . [17]

When looking at models of a gear wheel made using artificial intelligence algorithms, at first glance the geometry may be considered correct. However, on detailed analysis, it becomes apparent that the dimensions of the gear wheel deviate from the original. The STL model contains many surface discontinuities, which, without repair procedures, disqualifies such a model as a model for physical prototyping. The model also has many inaccuracies, for example, each tooth has a slightly different outline and also, for example, the tooth spacing is not uniform. Such a wheel cannot be used to work in a gearbox. This means that modelling with artificial intelligence algorithms still needs further development work.

At the same time, there is no doubt that the development of artificial intelligence, also in the area of modelling, will continue, slowly displacing - as one may think - the human factor. For this reason alone, traditional legal solutions may prove to be inadequate for the existing challenges. This area is worth looking into.

6. Legal aspects of numerical modelling

[17] View of the model made with the artificial intelligence algorithm: a) STL model, b) model produced with a 3D printer using the FFF process

There is no doubt that the above-mentioned technological aspects of modelling, their application or functionality would not be possible in practice if it were not for legal regulations, whose aim is, among other things, to protect the creative process[18]. As the design of numerical models is carried out with the use of computer software, a number of important observations must be made in this area, both from a legal and a technological point of view[19].

Firstly, in order to undertake a numerical design activity, it is important to establish who is using the software enabling this design and on what terms. This is because the types of rights to use software known in practice may limit the way in which a particular design can be used (excluding it altogether or limiting it to non-commercial use)[20]. The extent of the entitlement to use the software is therefore important, usually resulting from the concluded licence agreement between the software supplier and the entitled user[21].

Secondly, navigating the software environment may also be relevant in relation to the legal relationship between the designer-creator and the right holder. For example, there are legal regulations according to which, in the case of employment of a designer-author at an academic institution, the latter has priority to publish the scientific work of an employee who created the work as a result of the performance of duties from the employment relationship[22]. This may be of significant importance in the situation of the commercial viability of a given design, especially in the case of creative modelling, but also in the case of reproductive modelling, to which - in many cases - copyright characteristics may also be ascribed.

Thirdly, in the situation of reproducible modelling, especially when it aims at obtaining information necessary to construct an equivalent of an already existing technical solution, it is important to pay attention to whether this modelling aims at achieving a certain functionality, bypassing the consequences resulting from copyright or patents. If this is the

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[18] G. N. Mandel, To Promote the Creative Process: Intellectual Property Law and the Psychology of Creativity Notre Dame Law Review2011, vol. 86, p. 1999-2026.

[19] E. Bonadio, H. F. Lopes,Bonadio, Enrico and Felisberto, Honor, A New 'Digital Replica' Right? The Recent US Copyright Office Proposal (October 24, 2024). Available at SSRN: https://ssrn.com/abstract=4997957 or http://dx.doi.org/10.2139/ssrn.4997957

[20] K. Madatli, Software License Agreements: Main Types, Legal Aspects, and Regulations, Baku State University Law Review 2015, vol. 2 issue 1, p. 118 ff.

[21] A.M. St. Laurent, Understanding Open Source and Free Software Licensing, Sebastopol, CA 2004, passim.

[22] N. Spahiu, H. Bajraktari, F. Lata, Ownership of Copyright in Works Created During Employment Relationships, European Journal of Economics and Business Studies 2017, no. 8, p. 186 ff.

case, the reproductive process may at the same time be associated with an infringement of intellectual property rights and the consequences resulting from such an infringement[23].

Fourthly, in the context of modelling involving artificial intelligence algorithms, important questions and challenges arise that may significantly affect traditional approaches to intellectual property rights, raising questions such as who is considered a creator[24]. Unbridled technological development has contributed to the fact that the results of creative output may not only come from human endeavours. Numerical models, as indicated, are now created semi-autonomously. However, the predictions of the application of artificial intelligence for the future, as well as the stir it is causing in society, must also raise questions in this area. It should be noted in this regard that, within the framework of the current law, it is impossible to identify a suitable entity or legal construct that could be qualified as the author of artificial intelligence works and that would at the same time take into account the labour and financial effort of the people creating artificial intelligence[25]. The ongoing discussion in legal science has not yet developed a single universally accepted concept. These concepts and the related possible legal regulations, due to the nature of this kind of creation (artificial intelligence is an element of the virtual world), should, in turn, be supranational, which creates additional difficulties. For today, this is certainly an area that requires further discussion.

7. Conclusions for Further Research

Computer-aided three-dimensional modelling is a fundamental step in the creation of numerical objects used in many areas of science technology art or medicine. The modelling process is determined by its purpose, which in turn corresponds to the requirements for the accuracy of the object's numerical and physical representation. Increasing requirements for reducing the time to create numerical models are leading to an increasing use of numerical tools using automatic numerical procedures and algorithms based on artificial intelligence. This type of modelling process may give rise to some formal and legal issues related , among

[23] C. Sganga, The right of reproduction, in:E.Rosati (ed), Research Handbook on EU Copyright Law, Routledge 2021, passim.

[24]Y. Werzansky-Orland, AI-Generated Content and the Question of Copyright, International Journal of Business Research 2024, No. 5, p. 2-20.

[25]B. Stępień-Załucka, Constitutional right to property - methods of violation and means of protection, C.H.Beck 2021

other things, copyright and creative rights of the numerical models made. These problems may have further implications related to their later commercial or non-commercial use, e.g. as character models or scenes created for computer games for sale. Such models may also have applications in the educational process e.g. to create virtual and augmented reality. Models of this type have requirements mainly in relation to three-dimensional geometry described numerically, for which the main criterion for evaluation is often a visual representation subject to subjective evaluation. This impression can be heightened by the application of a texture, the purpose of which is, in a sense, to improve the visual effect of the developed numerical models. This can also be seen by looking at examples of object modelling software using artificial intelligence algorithms. In many cases, objects presented together with textures. Here, the question may also arise regarding such a model in what part one may have copyright in the model, whether e.g. for a three-dimensional model developed by an algorithm we can apply an authored texture or vice versa. Another question of ownership concerns the possibility to make changes to the model developed by the algorithm ourselves.

This publication is a contribution of sorts to the further discussion on the intellectual property rights of three-dimensional numerical objects produced in whole or in part using algorithms based on artificial intelligence. Bearing in mind that, as technology advances, the direct role of humans in algorithmic creativity is likely to become less and less, it is still an open question whether these algorithms can be considered as tools in the hands of the author or the author of the implemented concept, which would suggest the need to move away from traditional legal concepts according to which only humans can be the subject of copyright.

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