



(51) International Patent Classification:

B29C 64/386 (2017.01) B33Y 50/00 (2015.01)

B29C 64/393 (2017.01) B33Y 80/00 (2015.01)

B33Y 50/02 (2015.01)

(21) International Application Number:

PCT/US2018/030174

(22) International Filing Date:

30 April 2018 (30.04.2018)

(25) Filing Language:

English

(26) Publication Language:

English

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— as to the identity of the inventor (Rule 4.17(i))

Published:

— with international search report (Art. 21(3))

(54) Title: A 3D PRINTING COMPUTER APPLICATION 3D PRINTING USING THE SAME

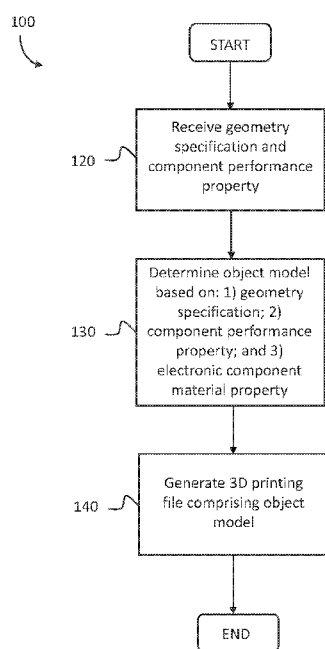


Figure 1

(57) Abstract: A method is disclosed for generating a 3D printing file containing an object model of a part having a body and an integral electronic component. To generate the 3D printing file, a processor receives at least one geometry specification of the part to be printed and at least one component performance property of the electronic component to be printed integral to the part. An object model is determined by the processor in accordance with the at least one geometry specification of a part to be printed, the at least one component performance property of an electronic component to be printed, and at least one material property of an electronic component printing material of a 3D printer. The 3D printing file is generated by the processor and comprises the object model.



A 3D PRINTING COMPUTER APPLICATION 3D PRINTING USING THE SAME

BACKGROUND

[0001] Apparatus that generate three-dimensional objects, including those commonly referred to as “3D printers”, can be used to produce three-dimensional objects. These apparatus may receive a definition of the three-dimensional object in the form of an object model. This object model is processed to instruct the apparatus to produce the object, for example, using a particulate material. The object may be produced on a layer-by-layer basis.

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] Various features and advantages will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, which together illustrate, given by way of example, features of the present disclosure, wherein:

[0003] Figure 1 is a flowchart illustrating a method, according to an example.

[0004] Figure 2 is a flowchart illustrating a method, according to a further example.

[0005] Figure 3 is a schematic diagram of a processing engine, according to an example.

[0006] Figure 4 is a schematic diagram of the processing engine of Figure 3, according to an example.

DETAILED DESCRIPTION

[0007] In the following description, for purposes of explanation, numerous specific details of certain examples are set forth. Reference in the description to "an example" or similar language means that a particular feature, structure, or characteristic described in connection with the example is included in at least that one example, but not necessarily in other examples.

[0008] 3D printing generally involves generating a 3D geometric representation of at least one part to be printed (i.e., manufactured by an additive manufacturing system such as a 3D printing system). Such a 3D geometric representation may be referred to as an object model that may be stored in a 3D data file using an appropriate file format. An object model may also define at least one material to be used to form the object. In some examples, an object model may define a first material to be used to form a first portion of an object and a second material to be used to form a second portion of that object. The 3D data file may be processed to generate instructions that are processed by a 3D printing system for reproducing the object. There are a variety of approaches for processing information in a 3D data file and enabling a user to define how an object should be manufactured using a 3D printing system.

[0009] It will be appreciated that 3D printing can be used to print a part into which an electronic component may subsequently be embedded or fitted. In other words, the embedding process happens after the part has been manufactured. The embedding process may be a manual or an automated manufacture process. In some cases, due to size, shape, or structural limitations of the printed part, a fully assembled electronic component may not be able to be inserted within the confines of the printed part to be embedded within or fitted to the printed part. In such scenarios, component parts of the electronic component may be inserted into an enclosure of the printed part, independently from one another, and, subsequently, arranged and assembled into a fully assembled electronic component within the enclosure of the printed part before the embedding or fitting process is carried out. For example, an electronic component may be assembled within a volume or cavity defined by the printed part before the embedding or

fitting processes are implemented. As such, the embedding process can be time consuming, resulting in a reduction in throughput of a 3D printer and an overall increase in the time needed to produce a complete part having an embedded electronic component. In addition, the embedding of the electronic component may decrease the effectiveness of the electronic component. For example, the electronic component may be designed so that it is appropriate for a post-part production embedding process. As such, the design of such an electronic component may be limited to being able to withstand a manual or machine automated embedding process. In addition, the design of an electronic component may be limited to ensure that the electronic component can be assembled within the confines of a printed part. These limitations may restrict the performance capability of the electronic component.

[00010] In addition, in some cases, in order for the part to withstand the manual or machine automated embedding process, the design specification of the body of the part may be restricted to ensure that such an embedding process can occur. For example, the body may be designed so that the body does not exceed a certain rigidity so that the body may be manipulated when the electronic component is embedded or assembled. These limitations may restrict the performance capability of the electronic component.

[00011] Accordingly, an example of a method of 3D printing a part and an electronic component is provided. An example computer-implemented method of generating a 3D printing file for a part comprising a body and an electronic component comprises receiving, by a processor at least one geometry specification of a part to be printed and at least one component performance property of an electronic component to be printed. The example method further comprises determining, by the processor, an object model, based on at least one geometry specification of a part to be printed, the at least one component performance property of an electronic component to be printed, and at least one material property of an electronic component printing material of a 3D printer. The example method further comprises generating, by the processor, a 3D printing file comprising the object model. In this way, the example method enables a 3D printing file to contain an object model that satisfies specifications relating to the

electronic component and the part overall. In addition, the example method provides a way of designing and subsequently printing an object model for a part having an integral electronic component, where the object model ensures the performance of the electronic component meets a desired performance level or capability.

[00012] The method generates a 3D printing file containing an object model that is based on both the desired part specifications and the desired electronic component specifications.

[00013] Furthermore, the subsequent 3D printing using a 3D printing file generated by the example method prints both the body of the part and the electronic component of the part together, for example on a layer-by-layer basis, and thereby creates the desired part having an integrated or integral electronic component with a desired performance capability from the 3D printing file, without the need for a manual post-part production process to embed or assemble the component within the printed part to form the end product. In this way, down-time of a 3D printing system may be reduced thereby reducing manufacturing and development costs.

[00014] The example method may be implemented by a computer processor. In a further example, the example method may be implemented through a computer application.

[00015] Figure 1 is a flowchart illustrating a method 100 of generating a 3D printing file for a part having a body and an electronic component, according to an example. The method 100 begins at block 120, where a processor receives at least one geometry specification of the part to be printed and at least one component performance property of the electronic component to be printed.

[00016] The at least one geometry specification of the part to be printed may be one of the following: a dimension; a shape; a volume; a height; a width; a depth; and a curvature. The at least one component performance property may be a specified criteria and may be of at least one of the following: conductance; resistance; capacitance; and a dielectric property.

[00017] At block 130, the processor determines, an object model for the part, based on the at least one geometry specification of the part to be printed,

the at least one component performance property of the electronic component to be printed, and at least one material property of an electronic component printing material of a 3D printer.

[00018] The at least one material property of the electronic component may be a specified criteria and may be at least one of the following: a conductive property, for example a conductive agent doping intensity; a resistive property; a dielectric property; and a metallic property. In some examples, the electronic component may comprise at least one conductive material and at least one dielectric material, in such cases, the at least one material property may define at least one conductive property of the conductive material and at least one dielectric property of the dielectric material. The at least one material property may be a property specified at a voxel level of a digital representation of the printing material, for example, a voxel level of an object model, where a voxel of an object model may be generated in a printed part as a result of printing one or more printing materials.

[00019] In one example, the object model may be determined based on at least one material property of the part body to be printed.

[00020] In one example, a material property of the electronic component printing material, for example a dielectric property, may be the same as a material property of the part body, such that a dielectric material of the electronic component is the same as a dielectric material of the part body.

[00021] Following the determination of block 130, the method 100 proceeds to block 140, where the processor generates a 3D printing file comprising the at least one object model.

[00022] The 3D printing file may be sent to a 3D printer (see element 300 of Figure 4) so that the part according to the object model of the 3D printing file can be printed. In one example, the 3D printing file is provided to a 3D printer that has the capability to produce parts containing different materials, such as conductive and non-conductive materials. In one example, the 3D printing file is provided to a 3D printer that has the capability to change conductive properties of its printing material, in accordance with the object model of the 3D printing file. A further

example of a 3D printing system, to which the 3D printing file may be provided is a fused deposition modelling (FDM) 3D printing system.

[00023] The electronic component may be at least one of the following: a conductive element; a conductive trace; an antenna; a passive adaptation element, for example a capacitor or an inductor; a resistor; and a connector. In one example, the body and the electronic component may, together, form an antenna having conductive and non-conductive portions, thereby being printed from a conductive material and a non-conductive (dielectric) material.

[00024] Referring to Figure 2, the determination of block 130 in the method 100 is described in more detail. The determination of block 130 begins at block 132 where a plurality of electronic component configurations that satisfy the at least one geometry specification of the part to be printed and the at least one component performance property of the electronic component are identified. The process of block 130 works to determine configurations that enable the electronic component to fit within the size and shape of the part to be printed. In one example, the process of block 130 may identify configurations that allow the electronic component to be as large as possible within the geometry of the printed part, that is, within the external surface of the part body. In one example, the plurality of electronic component configurations may be retrieved by performing a look-up or search operation on a configuration library containing various electronic component configurations.

[00025] In one example, the electronic component to be printed may be an antenna. In such a case, the configuration library may contain a number of antenna primitives each of which may define different antenna shapes, for example, a loop antenna, an F antenna, an inverted F antenna, and a planar antenna.

[00026] Next, the method 130 proceeds to block 134, where operation of an electronic component in each of the plurality of electronic component configurations is simulated. The simulation occurs based on the identified

configurations and the at least one material property of an electronic component printing material.

[00027] In the case where the configuration library contains antenna primitives, the simulation of block 134 may simulate each of the identified antenna primitives based on the material property of antenna printing material of a 3D printer to which the 3D printing file may be provided. The simulation may be carried out by an electromagnetic simulator. For example, an electromagnetic simulator that has the ability to simulate performance of electronic components for example, performance of at least one of: a conductive element; a conductive trace; an antenna; a passive adaptation element, for example a capacitor or an inductor; a resistor; and a connector.

[00028] In one example, the simulation may model the identified configurations in scaled up or down versions that would correspond to the size and shape of the configurations as if they were incorporated into the printed part.

[00029] In one example, the simulation of block 134 may comprise a plurality of phases. A first phase may be a modification phase in which each of the identified configurations is modified to provide a component performance property that is as close as possible to or the same as the at least one component performance property of the electronic component. The component performance property of an identified configuration may be the same as the at least one component performance property of the electronic component when there is no variation between the two or when such variation has a negligible effect on the component performance. In the latter scenario, such a variation may be defined by percentage difference or equivalent. The component performance property of the identified configuration may be as close as possible to the at least one component performance property of the electronic component when no further modifications can be made to the electronic configuration that will bring the component performance closer to or within a threshold from the at least one component performance property of the electronic component.

[00030] In another example, the component performance property of the identified configurations may be as close as possible to the at least one component performance property of the electronic component when a threshold

number of modifications have been made to the electronic component configuration.

[00031] As an example, where the electronic component is an antenna and the at least one component performance property of the electronic component is an operating frequency the modification phase may scale the size of the identified configurations up or down. In another example, where the electronic component is a capacitor and the at least one component performance property of the electronic component is a capacitance, the modification phase may scale one or more of the surface sizes of the identified configurations of the capacitor and the distance between the surfaces of the identified configurations of the capacitor. Following the modification, the modified electronic component configurations may be allocated to the part to be printed. A second phase of the simulation of block 134 may be an iteration phase, where performance of each modified electronic component configuration is simulated and then evaluated. Further simulations may be based on the evaluation. In more detail, performance of a first electronic component configuration may be simulated and subsequently evaluated. The evaluation of the first electronic component configuration may form part of a feedback loop in the iteration phase. The evaluation may provide feedback that causes a change in a variable defining the first electronic component configuration. Following this change, performance of the latest version of the first electronic component configuration may be simulated and the iteration process may be repeated until the evaluation determines that the configuration in question provides a satisfactory outcome.

[00032] In another example, the evaluation of the performance of the first electronic component configuration may provide feedback that causes performance of a second electronic component configuration to be simulated. This may occur when the first electronic component configuration is deemed to provide a satisfactory level of performance.

[00033] The iteration phase may continue until performance of each identified electronic component configuration has been simulated and evaluated. The evaluation of each electronic component configuration may be stored. In one example, the evaluation may include a scoring process where each simulation

(each identified electronic component configuration) is scored and evaluated relative to the other simulations.

[00034] In one example, the iteration phase may be followed by an assessment phase that ranks the electronic component configurations based on their respective simulation evaluations or scores. In one example, the assessment phase may discard one or more electronic configurations based on their ranking. In a further example, the assessment phase may initiate further iteration of one or more electronic configurations based on their ranking.

[00035] Following the simulation of each of the electronic component configurations, at block 136, an electronic component configuration is selected based on the simulated operation. The selection is based on the electronic component configuration that provides component performance that is closest to the component performance property of the electronic component to be printed integral to the part. In one example, the selection may be based on the previously described assessment phase.

[00036] Next, at block 138, the object model is determined based on the selected electronic component configuration.

[00037] In one example, feedback may be provided to a user of a computer application implementing the methods 100 and 130. The user feedback may indicate that one or more of the geometry specification, the electronic component printing material, and the electronic component performance property cannot be met in generation of an object model. The user feedback may indicate proposed changes to one or more of the geometry specification, the electronic component performance property, the electronic component printing material, and the part body printing material in response one or both of the identification or simulation processes. As an example, a proposed change may be a proposed change to the at least one geometry specification of the part to be printed, such as an increase in size of the part.

[00038] A 3D printing file, containing an object model, generated, as described above, provides increased flexibility in part design, for example, part design of a part having an embedded antenna. In addition, such 3D printing files

can provide a tailored object model that meets at least one component performance property.

[00039] Figure 3 is a schematic diagram of a processing engine 200 for implementing the methods 100 and 130. The processing engine 200 has a plurality of sub-processing elements that implemented the methods described in relation to Figures 1 and 2. The processing engine 200 may be a part of a computing device, which provides a computer application that implements the methods described in relation to Figures 1 and 2 using the processing engine. The computer application may be one of a plurality of computer applications in a 3D printing application suite.

[00040] Referring to Figure 3, the processing engine 200 has a part specification processor 210, an electronic component printing material processor 220, and an electronic component performance processor 230. In addition, the processing engine has an electronic component configuration processor 240. The electronic component configuration processor 240 is communicatively coupled to the part specification processor 210 and the electronic component performance processor 230.

[00041] The processing engine 200 also has a simulation processor 250. The simulation processor 250 is communicatively coupled to the electronic component printing material processor 220 and the electronic component configuration processor 240.

[00042] The processing engine 200 also has a 3D printing file processor 260. The 3D printing file processor 260 is communicatively coupled to the simulation processor 250.

[00043] The part specification processor 210 provides at least one geometry specification of the part to be printed to the electronic component configuration processor 240 and the electronic component performance processor 230 provides at least one component performance property of the electronic component to be printed to the electronic component configuration processor 240.

[00044] Based on the received at least one geometry specification of the part to be printed and at least one component performance property of the

electronic component to be printed, the electronic component configuration processor 240 identifies a plurality of electronic component configurations that satisfy said geometry and performance specifications. In one example, the electronic component configuration processor 240 may be in communication with an electronic component configuration library that stores a plurality of electronic component configurations. The electronic component configuration processor 240 may perform a look up or search operation on such a library. As discussed above, for a case where the electronic component is an antenna the library may be an antenna primitive library.

[00045] The electronic component configuration processor 240 provides the identified electronic component configurations to the simulation processor 250. The simulation processor 250 receives at least one material property of the printing material of the electronic component to be printed from the electronic component printing material processor 220.

[00046] The simulation processor 250 simulates operation of an electronic component having the at least one material property and each of the identified electronic component configurations. An electronic component configuration is selected by the simulation processor 250 based on the results of the simulations. The selection may be based on how close the electronic configuration is to the at least one component performance property.

[00047] The simulation processor 250 provides the selected electronic component configuration, or data representative thereof, to the 3D printing file processor 260. The 3D printing file processor 260 generates an object model based on the selected electronic component configuration.

[00048] Figure 4 is a functional schematic diagram of interaction between the sub-processors of the processing engine 200 in implementing the methods 100 and 130. Figure 4 depicts the data transfers between the sub-processors of processing engine 200.

[00049] A data file 211 contains data that relates to the geometry specification of the part to be printed and a data file 231 contains data that relates to the at least one component performance property of the electronic component. The data files 211 and 231 form the basis of the operation of the electronic

component configuration processor 240 (see Figure 3) to identify a plurality of electronic component configurations that satisfy the geometry and performance specifications. These electronic component configurations are represented by a data file 241.

[00050] A data file 221 contains data that relates to the at least one material property of an electronic component printing material. The data file 221 and the data file 241 contain data that is the basis of the simulations performed by the simulation processor 250.

[00051] As described in relation to Figure 3, the selection of an electronic component configuration is based on the results of the simulations. A data file 251 contains data that relates to the selected configuration and is therefore based on at least part of the data within data file 241. The selected configuration is used to determine an object model for the part to be printed and a data file 261 contains data that relates to the 3D printing file containing the object model. The data 261 file is transmitted to a 3D printing system 300, such as a 3D printer, so that the part can be printed in accordance with the object model.

[00052] A 3D printing system may be configured to receive and print a part in accordance with a 3D printing file generated as described above.

[00053] Examples can be realized in any computer-readable media for use by or in connection with an instruction execution system such as a computer/processor based system or an ASIC (Application Specific Integrated Circuit) or other system that can fetch or obtain the logic from computer-readable media and execute the instructions contained therein. "Computer-readable media" can be any media that can contain, store, or maintain programs and data for use by or in connection with the instruction execution system. Computer readable media can comprise any one of many physical media such as, for example, electronic, magnetic, optical, electromagnetic, or semiconductor media. More specific examples of suitable computer-readable media include, but are not limited to, a portable magnetic computer diskette such as floppy diskettes or hard drives, a random-access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory, or a portable compact disc.

[00054] In one example, a computer readable medium may contain instructions, that when executed by a processor, cause the above-described methods to be implemented.

[00055] It is to be understood that any feature described in relation to any one example may be used alone, or in combination with other features described, and may also be used in combination with one or more features of any other of the examples, or any combination of any other of the examples. Furthermore, equivalents and modifications not described above may also be employed in any one example.

CLAIMS

1. A computer-implemented method of generating a 3D printing file comprising an object model of a part having a body and an integral electronic component, the method comprising:

receiving, by a processor:

at least one geometry specification of a part to be printed; and

at least one component performance property of an electronic component to be printed integral to the part;

determining, by the processor, an object model of the part, according to the at least one geometry specification of a part to be printed, the at least one component performance property of an electronic component to be printed, and at least one material property of an electronic component printing material of a 3D printer; and

generating, by the processor, a 3D printing file comprising the at least one object model.

2. The computer implemented method of claim 1, wherein, determining the object model comprises identifying, by the processor, a plurality of electronic component configurations that satisfy the at least one geometry specification of the part to be printed.

3. The computer-implemented method of claim 2, wherein determining the object model comprises:

simulating, by the processor, an operating performance of an electronic component having each of the determined plurality of electronic component configurations; and

selecting, by the processor, an electronic component configuration, of the plurality of simulated electronic component configurations, that is closest to the component performance property of the electronic component to be printed integral to the part.

4. The computer-implemented method of claim 3, wherein simulating the operating performance of an electronic component having each of the determined plurality of electronic component configurations comprises:

modifying each of the determined plurality of electronic component configurations to provide a component performance property that is the same as the at least one component performance property of the electronic component;

simulating the operating performance of a first determined electronic component configuration;

evaluating the simulated operating performance of the first determined electronic component configuration; and

modifying the first determined electronic component configuration based on the evaluation and simulating the operating performance of the modified first determined electronic component configuration; or

repeating the simulating and evaluating for a second determined electronic component configuration.

5. The computer-implemented method of claim 2, comprising:
retrieving, by the processor, the plurality of electronic component configurations from a configuration library.

6. The computer implemented method of claim 1, comprising receiving, by the processor:
at least one material property of a part printing material of the 3D printer.

7. The computer-implemented method of claim 6, wherein the least one material property of the part printing material is provided at a voxel level of a 3D printer on which the part is to be printed.

8. The computer-implemented method of claim 1, wherein the electronic component printing material comprises at least one conducting material and at least one dielectric material.

9. The computer-implemented method of claim 8, comprising receiving, by the processor:

at least one material property of a part printing material of the 3D printer, wherein the part printing material comprises at least one dielectric material, wherein the dielectric material of the part printing material is the same as the dielectric material of the electric component printing material.

10. The computer-implemented method of claim 1, wherein the least one material property of the electronic component printing material is provided at a voxel level of a 3D printer on which the part is to be printed.

11. The computer-implemented method of claim 1, wherein the electronic component to be printed comprises an antenna.

12. The computer-implemented method of claim 11, wherein the at least one component performance property is at least one of: an antenna operating frequency, an antenna gain, and an antenna directivity.

13. A computer-implemented method of printing a part in accordance with a 3D printing file comprising an object model of a part comprising a body and an integral electronic component, the method comprising:

receiving:

at least one dimensional specification of the part to be printed; and

at least one performance criterion of the electronic component to be printed integral to the part;

determining an object model of the part, according to the at least one dimensional specification of the part to be printed, the at least one performance criterion of the electronic component to be printed integral to the part and at least one criterion of an electronic component printing material of a 3D printer; and

generating a 3D printing file comprising the object model; and

printing the part in accordance with the 3D printing file.

14. A 3D printing system configured to print a part in accordance with the 3D printing file generated by method claim 1.

15. A computer readable medium device, comprising instructions that when executed by a processor, cause the method of claim 1 to be carried out.

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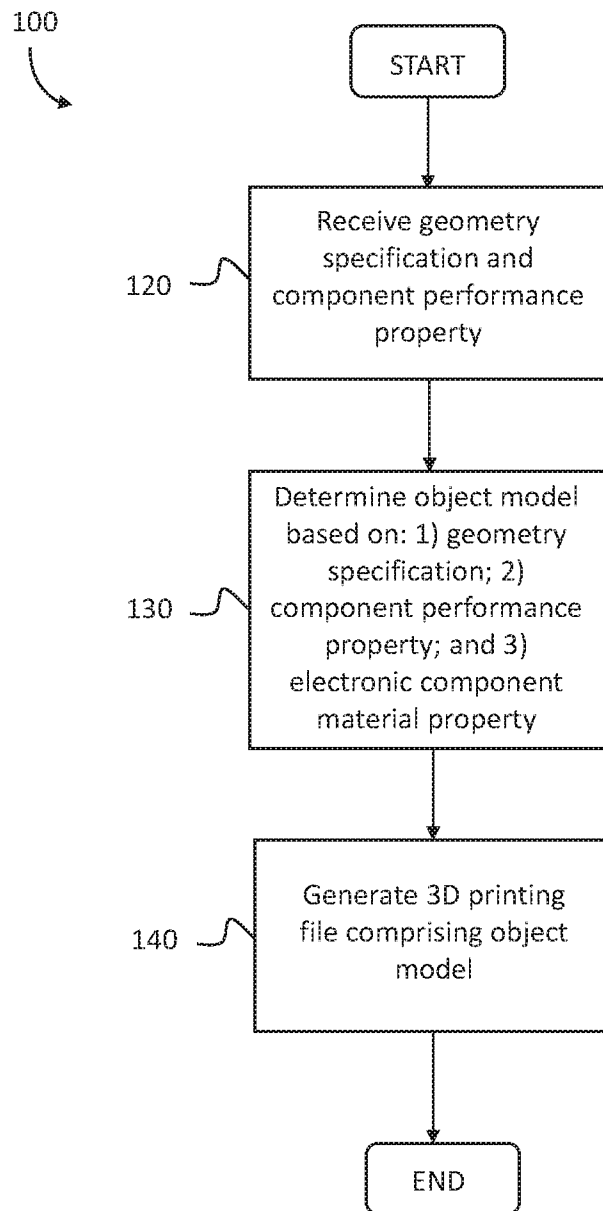


Figure 1

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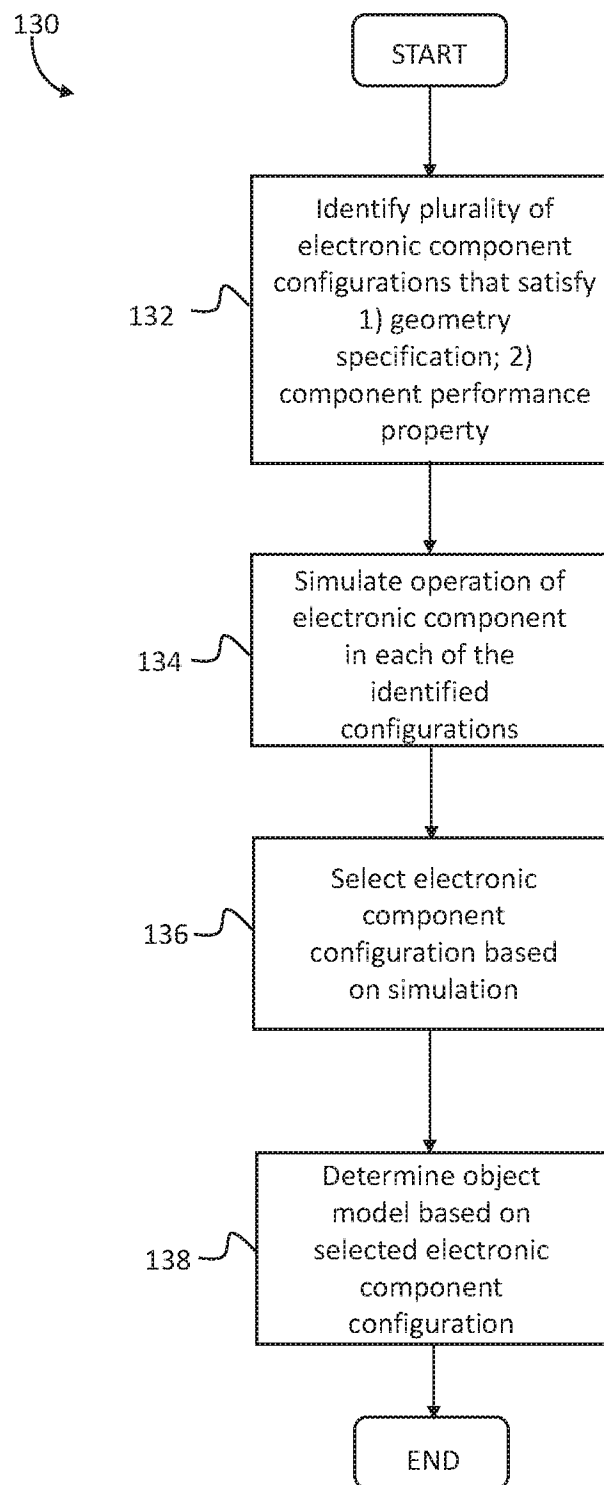


Figure 2

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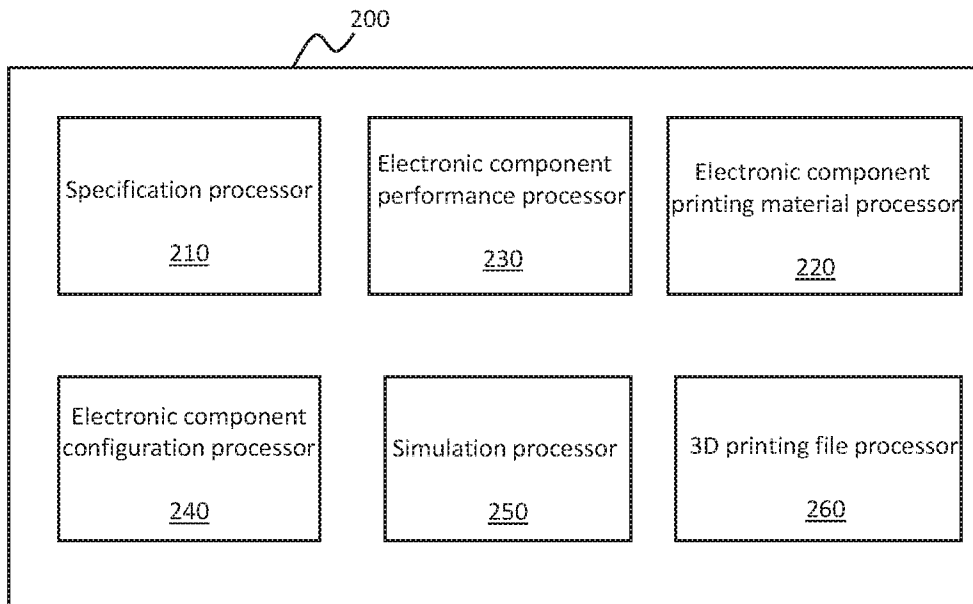


Figure 3

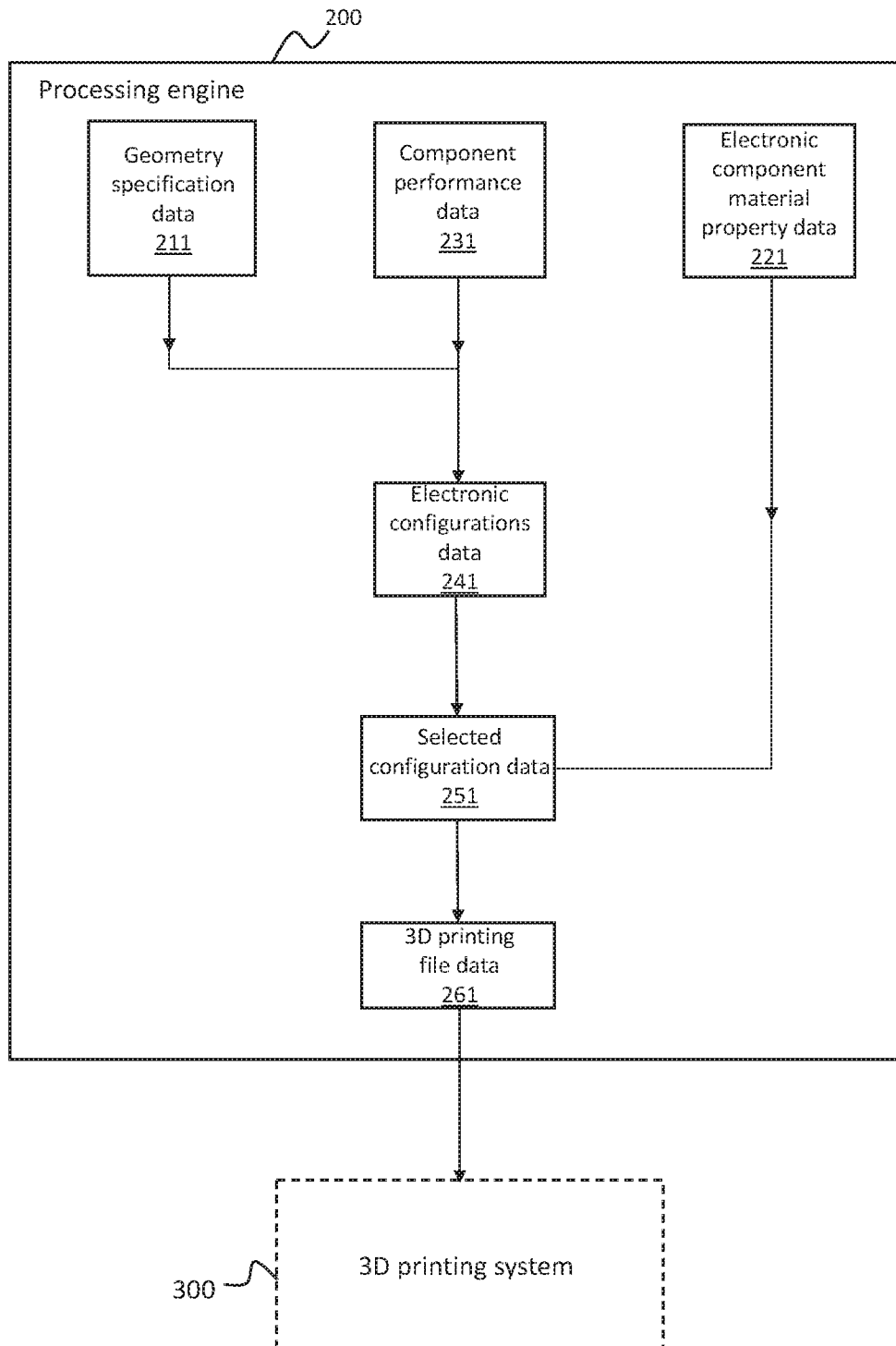


Figure 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 2018/030174

A. CLASSIFICATION OF SUBJECT MATTER (see extra sheet) According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) B29C, B33Y Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) PatSearch (RUPTO internal), Espacenet, DWPI, PAJ, USPTO, CIPO, PubMed		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2016/257074 A1 (XEROX CORP) 08.09.2016, claims 1, 2, 15, 19, [0005], [0013-0017], [0026-0027], [0031], [0033-0041], [0056-0060]	1-15
Y	US 2016/096318 A1 (DISNEY ENTPR INC) 07.04.2016, [0002-0006], [0009-0010], [0013], [0015-0021], [0034], [0043], [0046-0048], [0054], [0058], [0063], [0077-0078]	1-15
Y	WO 2017/074397 A1 (HEWLETT-PACKARD DEV COMPANY L P) 04.05.2017, [0003-0016], [0017], [0027], [0075], [0083], [0109]	1-15
Y	КОРОЛЕВ В. "Антенну для спутников напечатали на 3D-принтере", [27.09.18] из Интернет https://nplus1.ru/news/2016/03/16/3d-antenna 21.10.16 подтв. по адресу https://web.archive.org/web/20161021101747/https://nplus1.ru/news/2016/03/16/3d-antenna	11-12
A	US 2005/131657 A1 (SEAN MEI HSAIO L) 16.06.2005	1-15
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
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Date of the actual completion of the international search 28 September 2018 (28.09.2018)		Date of mailing of the international search report 22 November 2018 (22.11.2018)
Name and mailing address of the ISA/RU: Federal Institute of Industrial Property, Berezhkovskaya nab., 30-1, Moscow, G-59, GSP-3, Russia, 125993 Facsimile No: (8-495) 531-63-18, (8-499) 243-33-37		Authorized officer E. Druzhinina Telephone No. (8 499) 240-25-91

INTERNATIONAL SEARCH REPORT
Classification of subject matter

International application No.

PCT/US 2018/030174

B29C 64/386 (2017.01)

B29C 64/393 (2017.01)

B33Y 50/02 (2015.01)

B33Y 50/00 (2015.01)

B33Y 80/00 (2015.01)