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## PRINTING 3D OBJECTS

### BACKGROUND

**[0001]** Additive manufacturing is transforming classical part manufacturing processes, including removing many current limitations, leading to more complex object geometries using a simpler manufacturing process.

**[0002]** Some 3D printers can use different techniques to produce parts bearing different material properties such as, for example, conductive traces or passive electronic components like capacitors, inductors, resistors, antennas etc.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[0003]** Example implementations will now be described, by way of example, with reference to the accompanying drawings in which:

**[0004]** figure 1 is a schematic view of a 3-dimensional (3D) printing system according to example implementations;

**[0005]** figures 2A and 2B show stages in printing a 3D printed object with an embedded object according to example implementations;

**[0006]** figures 3A and 3B illustrate stages in printing a 3D printed object with an embedded object according to example implementations;

**[0007]** figures 4A and 4B depict stages in printing a 3D printed object with an embedded object according to example implementations;

**[0008]** figures 5A and 5B show stages in printing a 3D printed object with an embedded object according to example implementations;

**[0009]** figures 6A and 6B illustrate a stage in printing a 3D printed object with an embedded object according to example implementations;

**[0010]** figures 7A and 7B depict stages in printing a 3D printed object with an embedded object according to example implementations;

**[0011]** figure 8 shows a flowchart for controlling printing a 3D printed object with an embedded object according to example implementations;

**[0012]** figure 9 illustrates a flowchart for controlling printing a 3D printed object with an embedded object according to example implementations;

**[0013]** figure 10 depicts machine-readable storage and machine-executable instructions according to example implementations;

**[0014]**figure 11 shows a view of software, hardware or a combination of software or hardware for producing an output file, or data structure, for controlling a printer according to example implementations;

**[0015]**figure 12 illustrates a view of a flowchart of a method for producing the output file or data structure according to example implementations;

**[0016]**figure 13 depicts machine-executable instructions and machine-readable storage according to example implementations; and

**[0017]**figure 14 shows a data structure for controlling a 3D printer according to example implementations.

#### **DETAILED DESCRIPTION**

**[0018]**Figure 1 shows an example of 3D printing system 100. The system 100 may include a removable build chamber 110 on which a layer of build material can be deposited to form a build material bed 115. The build chamber can alternatively form a fixed part of the system 100. The build material can be, for example, a powder. In the example shown, the build chamber 110 has a build platform 120 bearing layers, or a volume, of build material to be selectively solidified to form each layer of a 3D object or part to be printed.

**[0019]**Examples of one or more build materials can comprise at least one of a polymer powders, or other plastic powder, a metal powder, a ceramic powder or other powder-like material, or lengths or units of such build material, taken jointly and severally in any and all permutations. The lengths or units of build material can comprise fibres or threads of build material. The fibres or threads of build material can be formed from, or otherwise derived from, longer or larger units of build material. The build material can be responsive to heat, or a binding agent, to fuse, or bind, particles of build material. For example, the build material to be fused can be defined with a printing liquid. The printing liquid can be arranged to couple heat to the build material to cause build material particles to fuse together. In other examples, a printing liquid may cause or influence chemical binding of the build material. Furthermore, the chemically bound build material can be subjected to heat to fuse the chemically bound build material together.

**[0020]**The system 100 can also comprise an inkjet printer 130 that has one or more than one inkjet pen for printing liquids. For example, the system 100 can

provide a first inkjet pen 135 in communication with a first reservoir 140 of a first printing liquid. Example implementations can be realised in which the printing liquid is a fusing agent. The system can also provide a second inkjet pen 145. The second inkjet pen 145 can be in communication with a second reservoir 150 of a second printing liquid. Example implementations can be realised in which the second printing liquid can be a detailing agent.

**[0021]** At least one of the first and second inkjet pens 135 and 145 can be used to influence use of the build material to construct a 3D object 178. For example, the fusing agent printed via the pen 135 can define the build material to be fused.

**[0022]** After the fusing agent has been printed onto the layer of build material, a heater such as, for example, a fusing lamp 160, can be used to heat the build material. Build material bearing fusing agent absorbs more energy than build material without fusing agent such the former coalesces, fuses, and solidifies (upon cooling) whereas the latter does not fuse. The fusing lamp is an example implementation of a heat source.

**[0023]** The detailing agent can be used to improve the definition between fused and unfused portions of build material during heating. The detailing agent is printed onto build material intended to remain unfused that is adjacent to build material intended to be fused. The detailing agent may, for example, influence the temperature of the build material onto which it is printed to inhibit fusing of that build material. The detailing agent can constrain thermal bleed, that is, it can constrain the inadvertent spread of heat to build material intended to remain unfused.

**[0024]** To achieve good selectivity between the fused and unfused portions of a build material layer, the fusing agent can absorb enough energy to increase the temperature of any build material coated or printed with the fusing agent above the melting or softening point of the build material, while unprinted portions of the layer of build material remain below the melting or softening point.

**[0025]** A controller 170 controls the operation of the 3D printer 100. The controller 170 can comprise one or more than one processor for executing machine-readable or machine-executable instructions for realizing any and all examples herein. Accordingly, examples provide at least one or more than one of circuitry,

hardware or software for implementing such a controller 170, taken jointly and severally in any and all permutations. The controller 170 is arranged to implement any control and/or any methods described herein.

**[0026]** The 3D printer 100 also comprises an arm 172. The arm 172 is controlled by the controller 170. The arm 172 is arranged to be able to pick an object 174 for placement into a void 176 of the 3D object 178. Therefore, example implementations of an arm can comprise at least one of an articulated arm, a gripping assembly, a gantry, or other picking and placing assembly, taken jointly and severally in any and all permutations. The object 174 can be stored on an object storage platform 180 prior to being embedded within the object 178. The arm 172 can be arranged to place the object 174 anywhere the void 176 is located. Figure 1 shows in dashed-line form the object 174 placed in the void 176.

**[0027]** The 3D object 178 comprise at least two 3D printed portions. The 3D object 178 can comprise at least a 3D printed portion that is printed in advance of receiving the embedded object 174. The 3D object 178 can comprise a further 3D printed portion 179 that is printed after the embedded object 174 has been placed within the void 176 of the 3D object 178. The further 3D printed portion 179 is also shown in dashed-line form.

**[0028]** The controller 170 controls the arm 172 to pick and place the object 174 into the void 176 of the 3D object 178.

**[0029]** Example implementations of the 3D printer 100 also provide an extraction arrangement 181 such as, for example, a build material remover (described with reference to figure 4), for removing build material from the build material bed. At least one, or both, of the extraction arrangement and build material remover are example implementations of an extractor.

**[0030]** Referring to figures 2A and 2B, there are shown views 200 of the stages of producing the void 176 in the 3D object 178. The 3D object 178 is constructed layer by layer by depositing and selectively solidifying the build material 202. Example implementations define the object 178 using at least one, or both, of the fusing agent or the detailing agent. A 3D printed container 204 is also printed layer by layer within the 3D object 178. The 3D printed container 204 can contain

a further 3D printed structure 206. The further 3D printed structure 206 is an example of a removable structure. Example implementations can provide a layer 208 of unfused build material between the further 3D printed structure 206 and the 3D printed container 204.

**[0031]** The 3D printed structure 206 defines the void 176. The 3D printed structure 206, forming the removable structure, can be at least one or more than one of the following taken jointly and several in any and all permutations:

**[0032]** (1) a solid volume of fused build material within the 3D printed container 204,

**[0033]** (2) a container comprising a fused shell housing unfused build material within an internal volume to form the removable structure defining the void, or

**[0034]** (3) an object of fused build material; the object of fused build material comprise, for example, a a sponge or mesh having one or more than one internal space, taken jointly and severally in any and all permutations, with the internal space or volume bearing unfused build material.

**[0035]** It will be appreciated that fusing the powder within the 3D printed container 204 to form the removable structure 206 defining the void comprises fusing the powder within the 3D printed container 204 to form the removable structure 206 with at least one fused powder portion defining at least one internal volume of unfused powder. Therefore, removing the 3D printed structure 206 also removes unfused build material within the container. Any such fused or unfused build material can be recycled.

**[0036]** Any and all implementations can be realised in which at least one, or both, of the removable structure or the 3D printed container are treated with an agent to facilitate removing the removable structure from the 3D printed container. For example, at least one, or both, of the removable structure or 3D printed container can be treated with an agent to facilitate removing the removable structure from the 3D printed container; in which the agent cools at least one, or both, of the removable structure or 3D printed container. Any such cooling of at least one, or both, of the removable structure or 3D printed container can increase the rigidity of the removable structure and/or the 3D printed container. Increasing the rigidity of the removable structure facilitates removing that structure more readily as

compared to its untreated state, in which it could be more flexible. Increasing the rigidity of the 3D printed container can improve the protection the 3D printed container provides against potential adverse influences on the 3D object that might arise from removing the removable structure or removing build material.

**[0037]** Example implementations can be realised in which treating at least one, or both, of the removable structure or 3D printed container with an agent to facilitate removing the removable structure from the 3D printed container comprises depositing a detailing agent or a cooling agent on at least one, or both, of the removable structure or 3D printed container to increase the rigidity of the removable structure or the 3D printed container.

**[0038]** For example, treating one or more than one layer of at least one, or both, of the removable structure or 3D printed container with an agent can facilitate removing the removable structure from the 3D printed container.

**[0039]** Further example implementations can provide for treating at least one, or both, of the removable structure or 3D printed container with an agent to facilitate removing the removable structure from the 3D printed container that comprises treating at least one or more of the removable structure, 3D printed container or adjacent unfused build material, taken jointly or severally in any and all permutations, with an agent to facilitate removing the removable structure from the 3D printed container. Still further example implementations can additionally or alternatively provide for cooling the unfused build material adjacent to fused build material to draw heat out of the fused build material to thereby cool and increase the rigidity of the fused build material.

**[0040]** Referring to figure 2B, it can be appreciated that the 3D printed structure 206 is in the process of being removed, which starts to create the void 176 into which the object 174 can be inserted.

**[0041]** Figure 3A is a view 300A showing the void 176 with the removable structure 206 having been completely removed. It can be appreciated that removing the 3D printed structure 206 has left a layer or lining 302 of build material within the 3D printed container 204. In example implementations, the remaining build material may not be free-flowing, which prevents the non-fused powder from moving in response to gravity. The dimensions of the 3D printed

container 204 and the 3D printed structure 206 can be selected according to how much or how little, if any, of the build material 302 should be retained within the 3D printed container 204. Example implementations can be realised in which a sufficient amount of build material 302 is retained between the 3D printed container 204 and the 3D printed structure 206 to provide at least one of sufficient spacing to allow an extraction arrangement or tool (not shown) to cooperate with the 3D printed structure 206 to remove it from the 3D printed container 204 or to influence, or reduce, at least one, or both, of frictional or mechanical coupling between the 3D printed container 204 and the 3D printed structure 206.

**[0042]** Figure 3B shows a view 300B in which the object 174 has been inserted into the void 176.

**[0043]** Referring to figure 4A, there is shown a view 400A of a stage of producing the void 176 in the 3D object 178 according to another implementation. The 3D object 178 is constructed, layer by layer, by depositing the build material 402 and defining the object 178 using at least one, or both, of the fusing agent or the detailing agent in cooperation with a heater such as, for example the lamp 160.

**[0044]** A 3D printed container 404 is also similarly printed, layer by layer, within the 3D object 178. The 3D printed container 404, in turn, can contain at least one, or both, of fused or unfused build material 406. The fused or unfused build material 406 can comprise a powder or an object of fused build material having one or more than one internal space or volume comprising unfused build material, taken jointly and severally in any and all permutations.

**[0045]** Figure 4B shows a view 400B of a further stage of producing the void 176. An extraction arrangement or tool, such as, for example, a build material remover 408, is provided to remove build material 406 from within the 3D printed container 404. An example implementation of a build material remover 408 is a vacuum pump. In the case of a vacuum pump, the build material is sucked out of the 3D printed container 404. It can be appreciated that a residual amount of the build material 406 is shown as remaining within the void 176 since it is in the process of being emptied. Alternatively, example implementations can be realised in which a predetermined amount of build material is intentionally retained within the void 176.

**[0046]** Referring to figure 5A, there is shown a view 500A of a stage of producing the 3D object 178 in which the build material has been removed from the 3D printed container 404.

**[0047]** Referring to figure 5B, there is shown a view 500B of a stage of producing the 3D object 178 in which the object 174 is situated within the void 176.

**[0048]** Referring to figure 6A, there is shown a view 600A of a further stage of producing the 3D object 178. The void 176 has been filled with build material 402. Refilling the void with build material 402 allows 3D printing to continue.

**[0049]** The build material 402 is deposited via a recoater 602. The recoater 602 is arranged to deposit a layer of build material during a traversal of the build platform 120. The recoater 602 has a predetermined clearance 604 relative to the bed of the build material 402 such that the depth of the build material is suitable to continue printing the 3D object 178. The recoater 602 moves in a reciprocating manner depositing build material. Build material progressively fills the void 176. When the void 176 has been sufficiently filled, printing of the 3D object 178 can resume.

**[0050]** Referring to figure 6B, there is shown a view 600B of a further stage of producing the 3D object 178. As described with reference to figure 6A, having prepared or otherwise conditioned the build material bed 402 for printing the further portion 179 of the 3D object 178, printing of the 3D printed object can resume. In the example implementation shown, the further portion 179 can comprise further side walls 606 of the 3D object 178 and a further side wall 608 of the 3D container 404. The additional side wall 608 of the 3D container 404 is arranged to maintain the embedded object within the 3D printed container.

**[0051]** Referring to figure 7A, there is shown a view 700A of the 3D printed container 204 and the 3D printed structure 206 together with the bed of build material 202. The view 700A is a close-up view of that given in figure 2A. An extraction arrangement or tool 702 is provided for removing the 3D printed structure 206 from the 3D printed container 204. The extraction tool comprises at least one 3D printed structure engagement member 704. Example implementations can be realised that provide a plurality of 3D printed structure engagement members 704. In the example implementation depicted, two 3D

printed structure engagement members 704 are shown.

**[0052]** The at least one 3D printed structure engagement member 704 is arranged to couple to, or otherwise cooperate or engage with, the 3D printed structure 206 to allow the 3D printed structure 206 to be removed from the 3D container 204.

**[0053]** The extraction tool 702 can also comprise at least one 3D printed container engagement member 706. Example implementations can be realised that provide a plurality of 3D printed container engagement members 706. In the example implementation depicted, two 3D printed container engagement members 706 are shown.

**[0054]** The at least one 3D printed container engagement member 706 is arranged to couple to, abut against, or otherwise cooperate with the 3D printed container 204 to assist in at least one, or both, of removing the 3D printed structure 206 from the 3D printed container 206 or to reduce the influence of removing the 3D printed structure 206 from the 3D printed container 206 on the 3D object 178 (not shown). For example, removing the 3D printed structure 206 from the build material bed 202 can transmit undesirable stresses or strains to, or otherwise adversely influence, the printed object 178.

**[0055]** The 3D object 178 can be designed or modified in light of any anticipated stresses or strains to, or otherwise adverse influences on, the printed object 178 as a consequence of at least one or more of creating the void, removing the build material to create the void or inserting the embedded object 174 taken jointly and severally in any and all permutations. For example, fused build material of the 3D object 178 such as the first 3D printed portion, can be arranged to have walls or other structures that increase resilience to deformation under any load that might experienced by the 3D object 178 due to at least one or more of creating the void, removing the build material to create the void or inserting the embedded object 174 into the void 176 taken jointly and severally in any and all permutations.

**[0056]** Accordingly, example implementations comprise selectively modifying or reinforcing at least one part of the 3D printed portion to accommodate removing the at least one, or both, of fused or unfused build material from the 3D printed container. It will be appreciated that selectively modifying or reinforcing at least one part of the 3D printed portion to accommodate removing the at least one, or

both, of fused or unfused build material from the 3D printed container 204 can comprise selectively modifying or reinforcing at least one part of the 3D printed portion to accommodate at least one or more than one of force, stress, shear or strain associated with removing the at least one, or both, of fused or unfused build material from the 3D printed container. The above described walls or other structures that increase resilience to deformation under load are examples of selectively modifying or reinforcing at least one part of the 3D printed portion.

**[0057]** The at least one 3D printed container engagement member can 706 remain stationary, abutting the 3D printed container 204, while the at least one 3D printed structured engagement member 704 is moved to remove the 3D printed structure 206.

**[0058]** Referring to figure 7B, it can be appreciated that the extraction tool 702 has raised the 3D printed structure 206 from the build material bed 202 thereby simultaneously removing the build material contained within or otherwise associated with the 3D printed structure 206 and creating the void 176.

**[0059]** Referring to figure 8, there is shown a view 800 of a flowchart according to an example implementation for embedding an object 174 within a 3D object 178 such as any one or more of the above described 3D objects.

**[0060]** At 802, a portion of the 3D object is printed, layer by layer, concurrently with also printing, in a similar manner, at least one, or both, of the 3D printed container or 3D printed structure.

**[0061]** At 804, the extraction tool 702 is used to remove the 3D printed structure to create the void 176.

**[0062]** The object 174 to be embedded within the 3D object 178 is picked at 806 and placed into the void 176 at 808.

**[0063]** At 810, the build material bed 202 is prepared such as, for example, levelled, in preparing to continue printing the 3D object 178 and printing of that object 178 is resumed once the build material bed is in a sufficient condition to support 3D printing, which comprises filling the void not taken by the embedded object 174. Any such preparing is an example of conditioning the build material bed for further printing such as, for example, printing the further portion 179, or any other portion, of the 3D object 178.

**[0064]** Referring to figure 9, there is shown a view 900 of a flowchart according to an example implementation for embedding an object 174 within a 3D object 178 such as any one or more of the above described 3D printed objects.

**[0065]** At 902, a portion of the 3D printed object is printed, layer by layer, concurrently with also printing, in a similar manner, at least the 3D printed container.

**[0066]** At 904, the build material remover 408 is used to remove the build material from within the 3D printed container to create the void 176. For example, the vacuum pump can be used to remove the build material from within the 3D printed container to create the void 176.

**[0067]** The object 174 to be embedded within the 3D object 178 is picked at 906 and placed into the void 176 at 908.

**[0068]** At 910, the build material bed 202 is prepared, such as for example, levelled, to prepare to continue printing the 3D object 178 and 3D printing of that object 178 is resumed. Any such preparing is an example of conditioning the build material bed for further printing such as, for example, printing the further portion 179, or any other portion, of the 3D object 178.

**[0069]** Example implementations can be realised in the form of machine-executable instructions arranged, when executed by a machine, to implement any or all aspects, processes, methods, operations, activities or flowcharts, taken jointly and severally in any and all permutations, described and/or claimed in this application. For example, the implementations shown in, or described with reference to, either, or both, of figures 8 or 9, can be realised at least in part using such machine executable instructions.

**[0070]** Therefore, implementations also provide machine-readable storage storing such machine-executable instructions. The machine-readable storage can comprise non-transitory machine-readable storage. The machine can comprise one or more processors, or other circuitry, for executing the instructions or implementing the instructions. For example, the controller 170 can process any such machine-executable instructions.

**[0071]** Referring to figure 10, there is shown a view 1000 of implementations of at least one of machine-executable instructions or machine-readable storage.

Figure 10 shows machine-readable storage 1002. The machine-readable storage 1002 can be realised using any type of volatile or non-volatile storage such as, for example, memory, a ROM, RAM, EEPROM, or other electrical storage, or magnetic or optical storage or the like. The machine-readable storage 1002 can be transitory or non-transitory. The machine-readable storage 1002 stores machine-executable instructions (MEIs) 1004. The MEIs 1004 comprise instructions that are executable by a processor or other instruction execution or instruction implementation circuitry 1006. The processor or other circuitry 1006 is responsive to executing or implementing the MEIs 1004 to perform any and all activities, processes, operations, methods or flowcharts described and/or claimed in this application.

**[0072]** The processor or other circuitry 1006 can output control signals 1008 for influencing the operation of one or more than one actuator 1010 for performing any and all operations, processes, activities, flowcharts or methods described and/or claimed in this application. The actuators 1010 can comprise mechanisms for controlling, or to control, for example, at least one or more than one of the inkjet printers, the arm, the extraction tool, the build material remover, the recoater or any other aspect of the 3D printer taken jointly and severally in any and all permutations.

**[0073]** The controller 170 can be an implementation of the foregoing processor or other circuitry 1006 for executing or implementing any such MEIs 1004.

**[0074]** The MEIs 1004 can comprise MEIs to implement the flowcharts of figures 8 and 9 or any part thereof taking jointly and severally with any other part thereof.

**[0075]** Referring to figure 11, there is shown a view 1100 of a system 1102 for processing a 3D object description to accommodate an embedded object. The system 1102 comprises a constructor 1104, which can be realised as software for processing a description 1106 of the 3D object and a description 1108 of an embedded object to produce an output file 1109 that can be processed by the system 100 to realise a 3D object 178 having an embedded object 174. The output file 1109 is an example of a data structure.

**[0076]** The description 1106 of the 3D object can be, for example, a 3D object definition file 1106. The 3D object definition file 1106 can be expressed using,

for example, a 3D Manufacturing Format (3MF) as specified by the 3MF consortium. Similarly, the embedded object description 1108 can be an embedded object definition file 1108 that is also expressed using 3MF. The embedded object file 1108 can comprise definitions of a number of features of the object to be embedded. In the example implementation shown, N such features are defined 1110, 1112, 1114. The 3D object definition file 1106 can comprise definitions of a number of features of the 3D object. In the example implementation shown, several such features 1116, 1118, 1120 are shown.

**[0077]** The constructor 1104 is arranged to process the embedded object definition file 1108 to determine at least one or more of the position, dimensions or shape, taken jointly and severally in any and all permutations, of the void to accommodate the embedded object within the 3D object. Software 1122 in the form of a void determining program or process can be used to determine at least one, or all, of shape, position or dimensions of the void 176 to accommodate the embedded object 174.

**[0078]** Having determined at least one, or all, of the dimensions, position or shape of the void to accommodate the embedded object, the constructor 1104 is arranged to create a definition of that void suitable for use in physically realising the 3D object 178 containing the void 176. Therefore, example implementations can be realised in which the constructor 1104 creates a definition file 1124 of at least one, or both, of the 3D printed container or the 3D printed structure described above. The definition file 1124 can also comprise the definition of the 3D object. The definition file 1124 is an example of a data structure.

**[0079]** The constructor 1104, knowing at least one of the position, dimensions or shape, taken jointly and severally in any and all permutations, of the void 176, creates control commands for removing build material to create the void 176. Removing the build material can comprise, as indicated above, using the build material remover, such as the vacuum pump, or the extraction tool for removing the 3D printed structure or unfused material. The constructor 1104 is also arranged to create control commands 1126 for controlling picking and placing the embedded object by the printer arm.

**[0080]** The constructor 1104 can also be arranged to perform an analysis of any

adverse consequences of placing the object within the 3D printed object, or of creating the void, on the first 3D printed portion of the 3D printed object. For example, various stresses or strains, or other adverse influences, may be predicted to deform the first 3D printed portion of the 3D printed object. The constructor 1104 can modify the design of the 3D printed object to counter or eliminate those adverse influences. For example, the constructor may alter wall thicknesses of potentially adversely affected parts of the 3D printed object.

**[0081]** Therefore, the output file 1109 can comprise at least one or more of the original or modified 3D printed object definition, the 3D printed container definition, the 3D printed structure definition, the embedded object pick and place control commands, or the recoater control commands, taken jointly and severally in any and all permutations. Although the system 1102 has been described above as a separate or stand-alone system, example implementations are not limited to such an arrangement. Example implementations can be realised in which the system 1102 forms part of the 3D printer 100.

**[0082]** Referring to figure 12, there is shown a view 1200 of a flowchart of the processing undertaken by the constructor 1104. At 1202, the definitions files 1106 and 1108 of the 3D printed object and the embedded object are imported. At least one or more of the position, dimensions or shape, taken jointly and severally in any and all permutations, of the void 176 to accommodate the embedded object is determined at 1204. At 1206, having determined at least one of the dimensions, position or shape of the void, the constructor 1104 determines at least one, or both, of the definitions of the 3D printed container or 3D printed structure used to create or otherwise realise the void.

**[0083]** The constructor 1104, knowing at least one of the position, dimensions or shape, taken jointly and severally in any and all permutations of, the void, creates control commands for removing build material to create the void. Removing the build material can comprise, as indicated above, using the build material remover, such as the vacuum pump, to remove the build material or the extraction tool for removing the 3D printed structure.

**[0084]** The position, shape or dimensions of the void facilitate the constructor 1104 producing the associated control commands or instructions for the printer

arm to pick and place the object 174 into the void 176.

**[0085]** At 1210, the output file 1109 is produced comprising printer data for realising at least one or more one of the 3D printed object, the 3D printed container, the 3D printed structure, the build material removal commands, the extraction arrangement control commands, the embedded object pick and place commands, or recoater control commands, taken jointly and severally in any and all permutations.

**[0086]** Example implementations of the system 1102 can be realised in the form of machine-executable instructions arranged, when executed by a machine, to implement any or all aspects, processes, activities or flowcharts, taken jointly and severally in any and all permutations, described in this application. For example, the implementations shown and/or described with reference to figure 12, can be realised at least in part using such machine executable instructions. It will be appreciated that circuitry as used herein can comprise one or more than one of physical electronic circuitry, software, hardware or application specific integrated circuitry, taken jointly or severally in any and all permutations.

**[0087]** Therefore, implementations also provide machine-readable storage storing such machine-executable instructions. The machine-readable storage can comprise transitory or non-transitory machine-readable storage. The machine can comprise one or more processors, or other circuitry, for executing the instructions or implementing the instructions.

**[0088]** Accordingly, referring to figure 13, there is shown a view 1300 of implementations of at least one of machine-executable instructions or machine-readable storage. Figure 13 shows machine-readable storage 1302. The machine-readable storage 1302 can be realised using any type of volatile or non-volatile storage such as, for example, memory, a ROM, RAM, EEPROM, or other electrical storage, or magnetic or optical storage or the like. The machine-readable storage 1302 can be transitory or non-transitory. The machine-readable storage 1302 stores machine-executable instructions (MEIs) 1304. The MEIs 1304 comprise instructions that are executable by a processor or other instruction execution, or instruction implementation, circuitry 1306. The processor or other circuitry 1306 is responsive to executing or implementing the MEIs 1304 to

perform any and all activities, processes, operations, methods or flowcharts described and/or claimed in this application such as the operations described with reference to at least one, or both, of figures 11 and 12, in particular for realising the processing undertaken by the constructor 1104 and for producing the output file 1109.

**[0089]** The processor or other circuitry 1306 can output the output file 1109. The output file 1109 comprises data, or instructions, to control the operations of the printer 100 in producing the 3D object 178 having an embedded object 174 within. Therefore, the output file 1109 can comprise data, or instructions, for controlling, or to control, for example, at least one or more than one of the inkjet printers, the arm, the extraction tool, the build material remover, the recoater or any other aspect of the 3D printer taken jointly and severally in any and all permutations.

**[0090]** The controller 170 can be an implementation of the foregoing processor or other circuitry 1306 for executing any such MEIs 1304.

**[0091]** The MEIs 1304 can comprise MEIs to implement the system of figure 11 and/or the flowchart of figure 12 or any part thereof taken jointly and severally with any other part thereof, and/or any method described herein. The MEIs 1304 comprise instructions arranged, when executed or implemented, cause the output file 1109 to be produced.

**[0092]** Referring to figure 14, there is shown a view 1400 of a data structure 1402 for producing or printing the 3D object 178 having the object 174 embedded therein. The above-described output file 1109 is an example of such a data structure 1402. It can be appreciated that the data structure 1402 comprises data 1404 for printing the 3D object 178 per se. The data structure 1402 comprises data 1406 for printing at least one, or both, of the 3D printed container or the 3D printed structure for creating the void. The data structure 1402 can also comprise data 1408 for creating the void by selectively removing build material to realise the void and/or for replacing the build material to condition the build material bed for continuing printing the 3D printed object. The data structure 1402 can also comprise data 1410 for controlling the arm to pick and place the object to be embedded within the 3D printed object.

**[0093]** An implementation of the data structure 1402 can comprise data or

instructions for performing any method claimed or described therein.

**[0094]** Any one or more of the example implementations described or claimed herein can provide the ability to print heterogeneous parts including multiple materials with different properties. Furthermore, example implementations support integrating pre-manufactured objects or devices within 3D printed objects without compromising the 3D printed object. The further object to be placed within the void can comprise at least one or more than one of a metal part or metal parts, electronic components or circuitry, wireless circuitry, battery or other power supply technology, taken jointly and severally in any and all permutations, subject to the further object being capable of withstanding the operating environment within the operational 3D printer 100. The operational environment within an operational 3D printer can comprise temperatures exceeding 200C.

**[0095]** Although example implementations have been described with reference to additive manufacturing within a 3D printer context, example implementations can be realised that apply to Selective Laser Sintering (SLS) systems and to metal binding.

**[0096]** Furthermore, it will be appreciated that the 3D printed object, the 3D printed container and the 3D removable structures are 3-dimensional, notwithstanding being shown in side or sectional views in the drawings. Still further, any or all of the 3D printed containers can have associated 3D printed support structures for maintaining the position of the 3D printed container relative to the 3D object. Yet further, any or all example implementations can further comprise internal support or retaining structures within the 3D printed container for maintaining the position of the embedded object relative to the 3D printed container. The internal support or retaining structures can comprise, for example, one or more than one resiliently deformable member arranged, when deformed to urge against the embedded object to retain the embedded object within a substantively fixed relationship to the 3D printed container.

**[0097]** It will be appreciated from the foregoing that an object can be embedded within the 3D object without interrupting or stopping the 3D printing process.

**[0098]** Implementations can be realised in accordance with the following examples:

**[0099]** Clause 1: A method for fabricating a 3D object comprising at least a 3D printed portion; the method comprising:

**[00100]** printing said at least a 3D printed portion of the 3D object; the 3D printed portion comprising a void for receiving a further object;

**[00101]** placing the further object within the void; and

**[00102]** printing at least a further 3D printed portion of the 3D object.

**[00103]** Clause 2: The method of clause 1, in which said printing the at least 3D printed portion of the object comprises creating the void for receiving the further object.

**[00104]** Clause 3: The method of clause 2, in which creating the void for receiving the further object comprises extracting at least one, or both, of fused or unfused build material from a build material bed associated with printing said at least a 3D object.

**[00105]** Clause 4: The method of clause 1, in which printing said at least a 3D printed portion comprises creating a 3D printed container (sarcophagus) comprising, defining, or associated with, the void for the further object.

**[00106]** Clause 5: The method of clause 4, comprising fusing build material within the 3D printed container to form a removable structure defining the void.

**[00107]** Clause 6: The method of clause 5, in which fusing the build material within the 3D printed container to form a removable structure defining the void comprises fusing the build material within the 3D printed container to form a respective build material bearing fabric.

**[00108]** Clause 7: The method of any of clauses 5 to 6, in which fusing the build material within the 3D printed container to form a removable structure defining the void comprises fusing the build material within the 3D printed container to form at least one fused build material portion defining at least one internal volume of unfused build material.

**[00109]** Clause 8: The method of any of clauses 5 to 7, comprising removing the removable structure to create the void.

**[00110]** Clause 9: The method of any of clauses 4 to 6, comprising extracting at least one, or both, of fused or unfused build material from within the

3D printed container to create the void.

**[00111]** Clause 10: The method of any of clauses 4 to 7, comprising printing at least one support structure to support the 3D printed container within the 3D printed portion of the 3D object.

**[00112]** Clause 11: The method of any of clauses 4 to 10, comprising using the 3D printed container (sarcophagus) as an extraction reference to aid in removing the at least one of fused or unfused build material from the 3D printed container.

**[00113]** Clause 12: The method of any of clauses 4 to 11, comprising distributing at least one of stress or strain over or throughout the 3D printed container during removing the at least one of fused or unfused build material from the 3D printed container.

**[00114]** Clause 13: The method of any of clauses 4 to 12, comprising decoupling at least one or more than one of force, stress, shear or strain associated with removing the at least one of fused or unfused build material from the 3D printed container from the 3D printed portion.

**[00115]** Clause 14: The method of any of clauses 4 to 13, comprising selectively modifying or reinforcing at least one part of the 3D printed portion to accommodate removing the at least one of fused or unfused build material from the 3D printed container.

**[00116]** Clause 15: The method of any of clauses 4 to 13, in which said selectively modifying or reinforcing at least one part of the 3D printed portion to accommodate removing the at least one of fused or unfused build material from the 3D printed container comprises selectively modifying or reinforcing at least one part of the 3D printed portion to accommodate at least one or more than one of force, stress, shear or strain associated with removing the at least one of fused or unfused build material from the 3D printed container.

**[00117]** Clause 16: The method of any of clauses 4 to 13, comprising providing an extraction tool to facilitate removing at least one of fused or unfused build material from the 3D printed container.

**[00118]** Clause 17: The method of any of clauses 4 to 16, providing an abutment associated with the 3D printed container with which the extraction tool

can cooperate in removing said at least one of fused or unfused build material from the 3D printer container.

**[00119]** Clause 18: The method of any of clauses 4 to 17, comprising providing a layer of unfused build material between the 3D printed container and the removable structure.

**[00120]** Clause 19: The method of any preceding clause, in which placing the further object within the void comprises picking the further object from a picking station, using an arm, and placing the further object in the void.

**[00121]** Clause 20: The method of any preceding clause, further comprising conditioning a build material bed associated with printing said at least 3D printed portion for said printing at least a further 3D printed portion of the object.

**[00122]** Clause 21: The method of clause 20, in which said conditioning comprises depositing one or more than one layer of build material over the build material bed.

**[00123]** Clause 22: The method of clause 21, in which said depositing comprises depositing one or more than one layer of build material over the build material bed using a recoater having a predetermined clearance relative to the build material bed to urge a surface of the build material bed towards a condition for printing said at least a further 3D printed portion of the object.

**[00124]** Clause 23: The method of clause 21 in which said depositing one or more than one layer of build material over the build material bed using a recoater having a predetermined clearance relative to the build material bed to urge a surface of the build material bed towards a condition for printing said at least said further 3D printed portion of the object comprises depositing one or more than one layer of build material over the build material bed using the recoater having a predetermined clearance relative to the build material bed to urge the surface of the build material bed towards a substantially planar state.

**[00125]** Clause 24: The method any of clauses 5 to 23, comprising treating at least one, or both, of the removable structure or the 3D printed container with an agent to facilitate removing the removable structure from the 3D printed container.

**[00126]** Clause 25: The method any clause 24, in which said treating at least one, or both, of the removable structure or 3D printed container with an agent to facilitate removing the removable structure from the 3D printed container comprises cooling at least one, or both, of the removable structure or 3D printed container.

**[00127]** Clause 26: The method of either of clauses 24 or 25, in which treating at least one, or both, of the removable structure or 3D printed container with an agent to facilitate removing the removable structure from the 3D printed container comprises depositing a detailing agent or a cooling agent on at least one, or both, of the removable structure or 3D printed container to increase the rigidity of the removable structure.

**[00128]** Clause 27: The method of any of clauses 24 to 26, in which treating at least one, or both, the removable structure or 3D printed container with an agent to facilitate removing the removable structure from the 3D printed container comprises treating one or more than one layer of at least one, or both, of the removable structure or 3D printed container with an agent to facilitate removing the removable structure from the 3D printed container.

**[00129]** Clause 28: The method any of clauses 24 to 27, in which treating at least one, or both, of the removable structure or 3D printed container with an agent to facilitate removing the removable structure from the 3D printed container comprises treating at least one or more of the removable structure, 3D printed container or adjacent unfused build material, taken jointly or severally in any and all permutations, with an agent to facilitate removing the removable structure from the 3D printed container.

**[00130]** Clause 29: The method any of clauses 5 to 28, comprising treating at least the 3D printed container with an agent to facilitate removing the removable structure from the 3D printed container.

**[00131]** Clause 30: The method any clause 29, in which said treating at least the 3D printed container with an agent to facilitate removing the removable structure from the 3D printed container comprises cooling at least the 3D printed container.

**[00132]** Clause 31: The method of either of clauses 29 or 30, in which

treating at least the 3D printed container with an agent to facilitate removing the removable structure from the 3D printed container comprises depositing a detailing agent or a cooling agent on at least the 3D printed container to increase the rigidity of the removable structure.

**[00133]** Clause 32: The method of any of clauses 29 to 31, in which treating at least the 3D printed container with an agent to facilitate removing the removable structure from the 3D printed container comprises treating one or more than one layer of at least the 3D printed container with an agent to facilitate removing the removable structure from the 3D printed container.

**[00134]** Clause 33: The method any of clauses 29 to 32, in which treating at least the 3D printed container with an agent to facilitate removing the removable structure from the 3D printed container comprises treating at least one of the 3D printed container or adjacent unfused build material with an agent to facilitate removing the removable structure from the 3D printed container.

**[00135]** Clause 34. An additive manufacturing printer for fabricating at least a 3D object comprising at least a 3D printed portion; the printer comprising at least one print head, a controller and an arm, in which controller comprises:

**[00136]** circuitry to control the at least one print head to print said at least a 3D printed portion of the 3D object; the 3D printed portion comprising a void for receiving a further object;

**[00137]** circuitry to control the arm to place the further object within the void; and

**[00138]** circuitry to control the at least one print head to print at least a further 3D printed portion of the 3D object.

**[00139]** Clause 35. The printer of clause 34, in which the controller comprises circuitry to control creating the void for receiving a further object.

**[00140]** Clause 36: The printer of clause 35, further comprising an extractor to extract at least one of fused or unfused build material from a build material bed associated with printing said at least a 3D object and in which the circuitry to create the void for receiving the further object comprises circuitry to control the extractor to extract at least one of fused or unfused build material from a build material bed associated with printing said at least a 3D object.

**[00141]** Clause 37: The printer of any of clauses 34 to 36, in which the controller comprises circuitry to control the at least one print head to create a 3D printed container (sarcophagus) comprising or defining the void for the further object.

**[00142]** Clause 38: The printer of any of clauses 34 to 37, comprising a heat source to fuse build material within the 3D printed container to form a removable structure defining the void.

**[00143]** Clause 39: The printer of clause 38, in which the circuitry to control fusing the build material within the 3D printed container to form a removable structure defining the void comprises circuitry to control the heat source to fuse the build material within the 3D printed container to form a respective build material bearing fabric and circuitry to control, using the heat source, fusing the build material within the 3D printed container to form a removeable structure defining the void.

**[00144]** Clause 40: The printer of any of clauses 38 to 39, in which the circuitry to control fusing the build material within the 3D printed container to form a removable structure defining the void comprises circuitry to control fusing the build material within the 3D printed container to form at least one fused build material portion defining at least one internal volume of unfused build material.

**[00145]** Clause 41: The printer of any of clauses 38 to 40, comprising an extractor to remove the removable structure to create the void.

**[00146]** Clause 42: The printer of any of clauses 37 to 39, in which the controller comprises circuitry to control extracting at least one of fused or unfused build material from within the 3D printed container to create the void.

**[00147]** Clause 43: The printer of any of clauses 37 to 40, in which the controller comprises circuitry to control printing at least one support structure to support the 3D printed container within the 3D printed portion of the object.

**[00148]** Clause 44: The printer of any of clauses 37 to 43, in which the controller comprises circuitry to control using the 3D printed container as an extraction reference to aid in removing the at least one of fused or unfused build material from the 3D printed container.

**[00149]** Clause 45: The printer of any of clauses 37 to 44, in which the

extractor is arranged to distribute at least one of stress or strain over or throughout the 3D printed container during removing the at least one of fused or unfused build material from the 3D printed container.

**[00150]** Clause 46: The printer of any of clauses 37 to 45, in which the 3D printed container is arranged to decouple at least one or more than one of force, stress, shear or strain associated with removing the at least one of fused or unfused build material from the 3D printed container from the 3D printed portion.

**[00151]** Clause 47: The printer of any of clauses 37 to 46, in which the controller comprises circuitry to control selectively modifying or reinforcing at least one part of the 3D printed portion to accommodate removing the at least one of fused or unfused build material from the 3D printed container.

**[00152]** Clause 48: The printer of any of clauses 37 to 47, in which said circuitry to control selectively modifying or reinforcing at least one part of the 3D printed portion to accommodate removing the at least one of fused or unfused build material from the 3D printed container comprises circuitry to selectively modify or reinforce at least one part of the 3D printed portion to accommodate at least one or more than one of force, stress, shear or strain associated with removing the at least one of fused or unfused build material from the 3D printed container.

**[00153]** Clause 49: The printer of any of clauses 38 to 48, in which the extractor or extraction tool can cooperate with an abutment associated with the 3D printed container in removing said at least one of fused or unfused build material from the 3D printed container.

**[00154]** Clause 50: The printer of any of clauses 38 to 49, in which the controller comprises circuitry to control providing a layer of unfused build material between the 3D printed container and the removable structure.

**[00155]** Clause 51: The printer of any of clauses 34 to 50, in which the circuitry to place the further object within the void comprises circuitry to pick the further object from a picking station, using an arm, and to place the further object in the void.

**[00156]** Clause 52: The printer of any of clauses 34 to 51, in which printer comprises a recoater for depositing build material and in which the controller

comprises circuitry to condition a build material or build material bed, associated with printing said at least 3D printed portion, for printing said at least a further 3D printed portion of the object.

**[00157]** Clause 53: The printer of clause 52, in which said circuitry to condition a build material or build material bed, associated with printing said at least 3D printed portion, for printing said at least a further 3D printed portion of the object comprises circuitry to control depositing one or more than one layer of build material over the build material bed.

**[00158]** Clause 54: The printer of clause 53, in which said circuitry to control depositing one or more than one layer of build material over the build material bed comprises circuitry to control depositing one or more than one layer of build material over the build material bed using a recoater having a predetermined clearance relative to the build material bed to urge a surface of the build material bed towards a condition for printing said at least a further 3D printed portion of the object.

**[00159]** Clause 55: The printer of clause 54, in which said circuitry to control depositing one or more than one layer of build material over the build material bed using a recoater having a predetermined clearance relative to the build material bed to urge a surface of the build material bed towards a condition for printing said at least a further 3D printed portion of the object comprises circuitry to control depositing one or more than one layer of build material over the build material bed using the recoater having a predetermined clearance relative to the build material bed to urge the surface of the build material bed towards a substantially planar state.

**[00160]** Clause 56: The printer any of clauses 38 to 55, in which the controller comprises circuitry to control treating at least the removable structure with an agent to facilitate removing the removable structure from the 3D printed container.

**[00161]** Clause 57: The printer of clause 56, in which said circuitry to control treating at least the removable structure with an agent to facilitate removing the removable structure from the 3D printed container comprises circuitry to control cooling at least the removable structure.

**[00162]** Clause 58: The printer of either of clauses 56 or 57, in which said circuitry to control treating at least the removable structure with an agent to facilitate removing the removable structure from the 3D printed container comprises circuitry to control depositing a detailing agent or a cooling agent on at least the removable structure to increase the rigidity of the removable structure.

**[00163]** Clause 59: The printer of any of clauses 57 to 58, in which said circuitry to control treating at least the removable structure with an agent to facilitate removing the removable structure from the 3D printed container comprises circuitry to control treating one or more than one layer of at least the removable structure with an agent to facilitate removing the removable structure from the 3D printed container.

**[00164]** Clause 60: The printer any of clauses 57 to 59, in which the circuitry to control treating at least the removable structure with an agent to facilitate removing the removable structure from the 3D printed container comprises circuitry to control treating at least one of the removable structure or adjacent unfused build material with an agent to facilitate removing the removable structure from the 3D printed container.

**[00165]** Clause 61: The printer any of clauses 38 to 60, in which the controller comprises circuitry to control treating at least the 3D printed container with an agent to facilitate removing the removable structure from the 3D printed container.

**[00166]** Clause 62: The printer of clause 61, in which said circuitry to control treating at least the 3D printed container with an agent to facilitate removing the removable structure from the 3D printed container comprises circuitry to control cooling at least the 3D printed container.

**[00167]** Clause 63: The printer of either of clauses 61 or 62, in which said circuitry to control treating at least the 3D printed container with an agent to facilitate removing the removable structure from the 3D printed container comprises circuitry to control depositing a detailing agent or a cooling agent on at least the 3D printed container to increase the rigidity of the removable structure.

**[00168]** Clause 64: The printer of any of clauses 61 to 63, in which said circuitry to control treating at least the 3D printed container with an agent to

facilitate removing the removable structure from the 3D printed container comprises circuitry to control treating one or more than one layer of at least the 3D printed container with an agent to facilitate removing the removable structure from the 3D printed container.

**[00169]** Clause 65: The printer any of clauses 61 to 64, in which said circuitry to control treating at least the 3D printed container with an agent to facilitate removing the removable structure from the 3D printed container comprises circuitry to control treating at least one of the 3D printed container or adjacent unfused build material with an agent to facilitate removing the removable structure from the 3D printed container.

**[00170]** Clause 66. A method of constructing a data structure associated with controlling a 3D printer to print a 3D object having an embedded object; method comprising:

**[00171]** processing a description of the 3D object and a description of the embedded object to determine at least one of dimensions, shape and position, taken jointly and severally in any and all permutations, of a void to accommodate the embedded object within the 3D object;

**[00172]** creating control instructions to control creating the void during printing the 3D object (ie control vacuum pump, or control extraction tool);

**[00173]** creating control instructions to place the embedded object within the void;

**[00174]** creating printing instructions:  
to print at least a 3D printed portion of the 3D object; the 3D object to comprise the void for receiving for embedded object, to print at least one entity such as, for example, at least one, or both, of a 3D printed container or 3D printed structure, associated with creating the void, and to print at least a further portion of the 3D object after the embedded object has been placed within the void.

**[00175]** Clause 67. The method of clause 66, comprising creating instructions to control creating the void for receiving a further object.

**[00176]** Clause 68: The method of clause 67, in which the printer comprises an extractor to extract at least one of fused or unfused build material from a build material bed associated with printing said at least a 3D object and in

which creating instructions to create the void for receiving the further object comprises creating instructions to control the extractor to extract at least one, or both, of fused or unfused build material from a build material bed associated with printing said at least a 3D object.

**[00177]** Clause 69: The method of any of clauses 66 to 68, comprising creating instructions to control the at least one print head to create a 3D printed container (sarcophagus) comprising or defining the void for the further object.

**[00178]** Clause 70: The method of clause 69, in which the printer comprises a heat source to fuse build material within the 3D printed container to form a removable structure defining the void; the method comprising creating instructions to control fusing the build material within the 3D printed container to form a removable structure comprising or defining the void for the embedded object.

**[00179]** Clause 71: The method of clause 70, in which the heat source to fuse the build material within the 3D printed container to form a removable structure defining the void and in which the method comprises creating instructions to fuse, using the heat source, the build material within the 3D printed container to form a respective build material bearing fabric.

**[00180]** Clause 72: The method of any of clauses 70 to 71, in which the instructions to control fusing the build material within the 3D printed container to form a removable structure defining the void comprises instructions to control fusing the build material within the 3D printed container to form at least one fused build material portion defining at least one internal volume of unfused build material.

**[00181]** Clause 73: The method of any of clauses 70 to 72, in which the printer comprises an extractor to remove the removable structure to create the void; the method comprising creating instructions to control the extractor to remove the removable structure to create the void.

**[00182]** Clause 74: The method of any of clauses 69 to 71, comprising instructions to control extracting at least one of fused or unfused build material from within the 3D printed container to create the void.

**[00183]** Clause 75: The method of any of clauses 69 to 72, comprising

instructions to control printing at least one support structure to support the 3D printed container within the 3D printed portion of the object.

**[00184]** Clause 76: The method of any of clauses 69 to 75, comprising instructions to control using the 3D printed container as an extraction reference to aid removing the at least one, or both, of fused or unfused build material from the 3D printed container.

**[00185]** Clause 77: The method of any of clauses 69 to 76, in which the extractor is arranged cooperate with (such as, for example, to distribute at least one of stress or strain over or throughout) the 3D printed container during removing the at least one, or both, of fused or unfused build material from the 3D printed container.

**[00186]** Clause 78: The method of any of clauses 69 to 77, in which the 3D printed container is arranged to decouple at least one or more than one of force, stress, shear or strain associated with removing the at least one, or both, of fused or unfused build material from the 3D printed container from the 3D printed portion.

**[00187]** Clause 79: The method of any of clauses 69 to 78, comprising instructions to control selectively modifying or reinforcing at least one part of the 3D printed portion to accommodate removing the at least one, or both, of fused or unfused build material from the 3D printed container.

**[00188]** Clause 80: The method of any of clauses 69 to 79, in which said instructions to control selectively modifying or reinforcing at least one part of the 3D printed portion to accommodate removing the at least one, or both, of fused or unfused build material from the 3D printed container comprises instructions to control selectively modifying or reinforcing at least one part of the 3D printed portion to accommodate at least one or more than one of force, stress, shear or strain associated with removing the at least one of fused or unfused build material from the 3D printed container.

**[00189]** Clause 81: The method of any of clauses 69 to 80, comprising instructions to control the extraction tool cooperating, via an abutment associated, with the 3D printed container in removing said at least one of fused or unfused build material from the 3D method container.

**[00190]** Clause 82: The method of any of clauses 69 to 81, comprising instructions to control providing a layer of unfused build material between the 3D printed container and the removable structure.

**[00191]** Clause 83: The method of any of clauses 66 to 82, in which the instructions to control placing the further object within the void comprises instructions to control picking the further object from a picking station, using an arm, and placing the further object in the void.

**[00192]** Clause 84: The method of any of clauses 66 to 83, comprising instructions to control depositing, via a recoater, build material and comprising instructions to control conditioning a build material bed associated with printing said at least 3D printed portion, for printing said at least a further 3D printed portion of the object.

**[00193]** Clause 85: The method of clause 84, in which said instructions to control conditioning a build material bed, associated with printing said at least 3D printed portion, for printing said at least a further 3D printed portion of the object comprises instructions to control depositing one or more than one layer of build material over the build material bed.

**[00194]** Clause 86: The method of clause 85, in which said instructions to control depositing one or more than one layer of build material over the build material bed comprises instructions to control depositing one or more than one layer of build material over the build material bed using a recoater having a predetermined clearance relative to the build material bed to urge a surface of the build material bed towards a condition for printing said at least a further 3D printed portion of the object.

**[00195]** Clause 87: The method of clause 86, in which said instructions to control depositing one or more than one layer of build material over the build material bed using a recoater having a predetermined clearance relative to the build material bed to urge a surface of the build material bed towards a condition for printing said at least a further 3D printed portion of the object comprises instructions to control depositing one or more than one layer of build material over the build material bed using the recoater having a predetermined clearance relative to the build material bed to urge the surface of the build material bed

towards a substantially planar state.

**[00196]** Clause 88: The method any of clauses 70 to 87, comprising instructions to control treating at least the removable structure with an agent to facilitate removing the removable structure from the 3D printed container.

**[00197]** Clause 89: The method of clause 88, in which said instructions to control treating at least the removable structure with an agent to facilitate removing the removable structure from the 3D printed container comprises instructions to control cooling at least the removable structure.

**[00198]** Clause 90: The method of either of clauses 88 or 89, in which said instructions to control treating at least the removable structure with an agent to facilitate removing the removable structure from the 3D printed container comprises instructions to control depositing a detailing agent or a cooling agent on at least the removable structure to increase the rigidity of the removable structure.

**[00199]** Clause 91: The method of any of clauses 89 to 90, in which said instructions to control treating at least the removable structure with an agent to facilitate removing the removable structure from the 3D printed container comprises instructions to control treating one or more than one layer of at least the removable structure with an agent to facilitate removing the removable structure from the 3D printed container.

**[00200]** Clause 92: The method any of clauses 89 to 91, in which the instructions to control treating at least the removable structure with an agent to facilitate removing the removable structure from the 3D printed container comprises instructions to control treating at least one, or both, of the removable structure or adjacent unfused build material with an agent to facilitate removing the removable structure from the 3D printed container.

**[00201]** Clause 93: The method any of clauses 70 to 92, comprising instructions to control treating at least the 3D printed container with an agent to facilitate removing the removable structure from the 3D printed container.

**[00202]** Clause 94: The method of clause 93, in which said instructions to control treating at least the 3D printed container with an agent to facilitate removing the removable structure from the 3D printed container comprises

instructions to control cooling at least the 3D printed container.

**[00203]** Clause 95: The method of either of clauses 93 or 94, in which said instructions to control treating at least the 3D printed container with an agent to facilitate removing the removable structure from the 3D printed container comprises instructions to control depositing a detailing agent or a cooling agent on at least the 3D printed container to increase the rigidity of the removable structure.

**[00204]** Clause 96: The method of any of clauses 93 to 95, in which said instructions to control treating at least the 3D printed container with an agent to facilitate removing the removable structure from the 3D printed container comprises instructions to control treating one or more than one layer of at least the 3D printed container with an agent to facilitate removing the removable structure from the 3D printed container.

**[00205]** Clause 97: The method any of clauses 93 to 96, in which said instructions to control treating at least the 3D printed container with an agent to facilitate removing the removable structure from the 3D printed container comprises instructions to control treating at least one or more of the 3D printed container or adjacent unfused build material with an agent to facilitate removing the removable structure from the 3D printed container.

**[00206]** Clause 98: Machine-executable instructions arranged, when executed by at least one processor, to implement a method of any of clauses 66 to 97.

**[00207]** Clause 99: Machine-readable storage storing machine-executable instructions of clause 98.

**[00208]** Clause 100: Machine-executable instructions arranged, when executed, to control a printer to implement a method of any of clauses 1 to 33.

**[00209]** Clause 101: Machine-readable storage storing machine-executable instructions of clause 100.

**CLAIMS**

1. A method for fabricating a 3D object comprising at least a 3D printed portion;  
the method comprising:  
printing said at least a 3D printed portion of the 3D object; the 3D printed portion comprising a void for receiving a further object;  
placing the further object within the void; and  
printing at least a further 3D printed portion of the 3D object.
2. The method of claim 1, comprising creating a void for receiving the further object, including extracting at least one of fused or unfused build material from a build material bed associated with printing said at least a 3D object.
3. The method of claim 1, in which printing said at least a 3D printed portion comprises creating a 3D printed container comprising or defining the void for the further object.
4. The method of claim 3, comprising fusing build material within the 3D printed container to form a removable structure comprising a respective build material bearing fabric associated with or defining the void.
5. The method of claim 4, comprising extracting at least one of fused or unfused build material from within the 3D printed container to create the void.
6. The method of claim 1, further comprising conditioning a build material bed associated with printing said at least 3D printed portion for said printing at least a further 3D printed portion of the 3D object.
7. The method of claim 4, comprising treating at least one, or both, of the removable structure or 3D printed container with an agent to facilitate removing the removable structure from the 3D printed container.

8. An additive manufacturing printer for fabricating at least a 3D object comprising at least a 3D printed portion; the printer comprising at least one print head, a controller and an arm, in which controller comprises:  
circuitry to control the at least one print head to print said at least a 3D printed portion of the 3D object; the 3D printed portion comprising a void for receiving a further object;  
circuitry to control the arm to place the further object within the void; and  
circuitry to control the at least one print head to print at least a further 3D printed portion of the 3D object.
9. The printer of claim 8, further comprising an extractor to extract at least one of fused or unfused build material from a build material bed associated with printing said at least a 3D object.
10. The printer of claim 8, in which the controller comprises circuitry to control the at least one print head to create a 3D printed container comprising or defining the void for the further object.
11. The printer of claim 10, comprising circuitry to control fusing the build material within the 3D printed container to form a removable structure defining the void comprising  
circuitry to control a heat source to fuse the build material within the 3D printed container to form a respective build material bearing fabric and  
circuitry to control, using the heat source, fusing the build material within the 3D printed container to form a removeable structure defining the void.
12. The printer of claim 11, comprising an extractor to remove the removable structure to create the void.
13. The printer of claim 8, comprising a recoater for depositing build material and in which the controller comprises circuitry to condition a build material bed,

associated with printing said at least 3D printed portion, for printing said at least a further 3D printed portion of the 3D object.

14. A method of constructing a data structure associated with controlling a 3D printer to print a 3D object having an embedded object; method comprising:
  - processing a description of the 3D object and a description of the embedded object to determine at least one of dimensions, shape or position of a void to accommodate the embedded object within the 3D object;
  - creating control instructions to control creating the void during printing the 3D object;
  - creating control instructions to place the embedded object within the void;
  - creating printing instructions:
    - to print at least a 3D printed portion of the 3D object; the 3D object to comprise the void for receiving the embedded object,
    - to print at least one entity associated with creating the void, and
    - to print at least a further portion of the 3D object after the embedded object has been placed within the void.
15. The method of claim 14, in which the printer comprises an extractor to extract at least one of fused or unfused build material from a build material bed associated with printing said at least a 3D object and in which creating instructions to create the void for receiving the embedded object comprises creating instructions to control the extractor to extract at least one, or both, of fused or unfused build material from a build material bed associated with printing said at least a 3D object.

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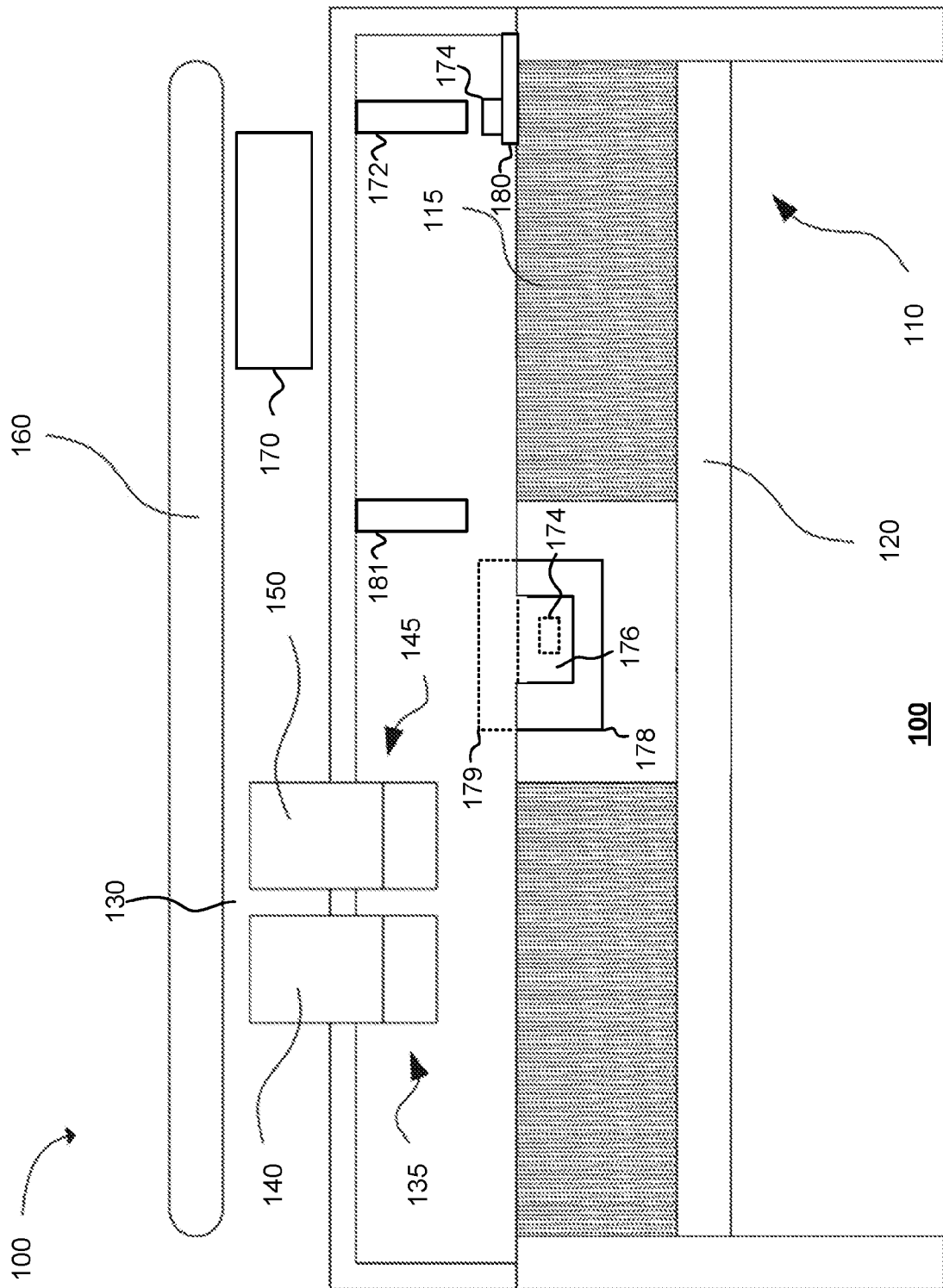


**FIG. 1**

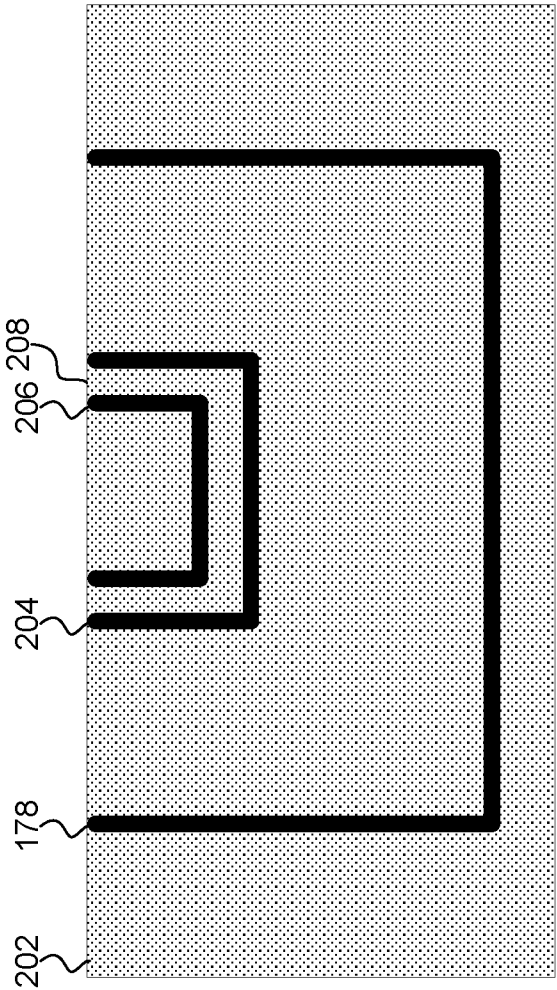


FIG. 2A

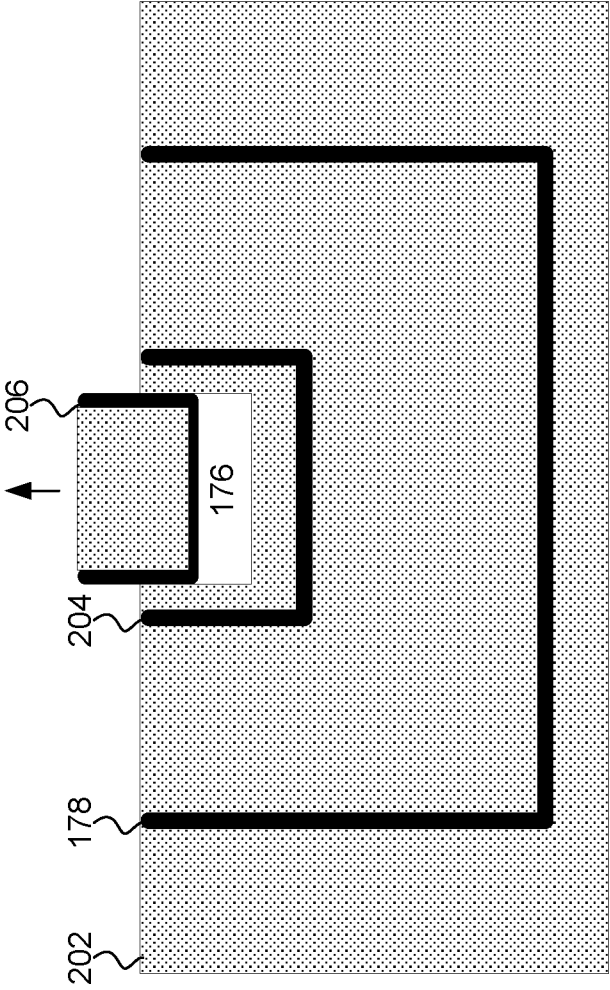


FIG. 2B

200

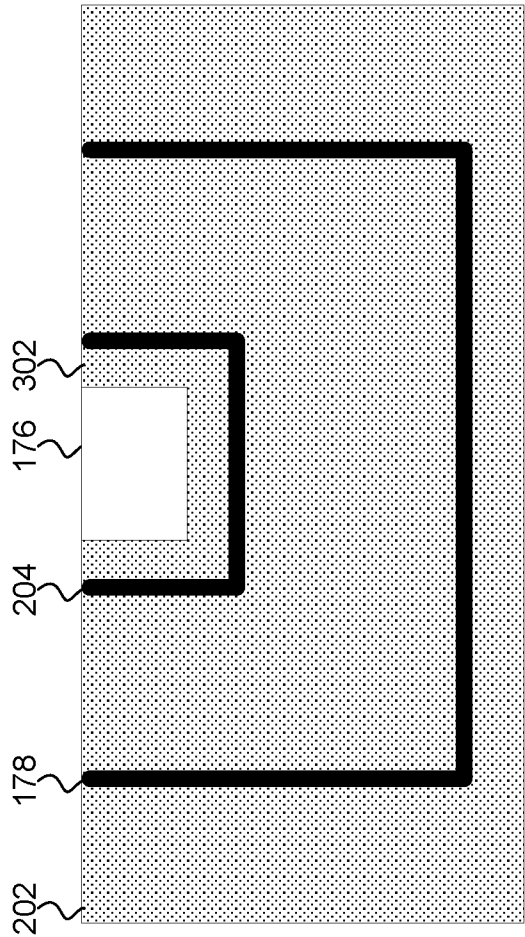


FIG. 3A

300A

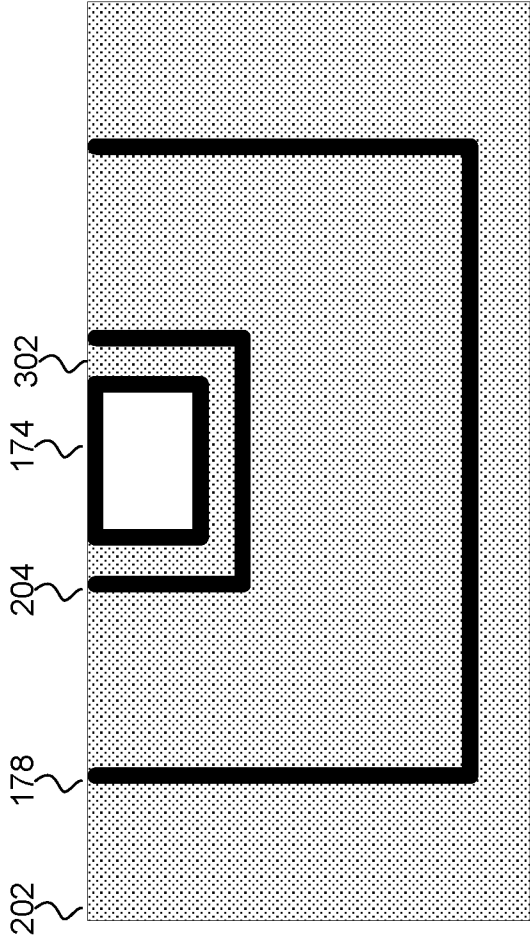


FIG. 3B

300B

300

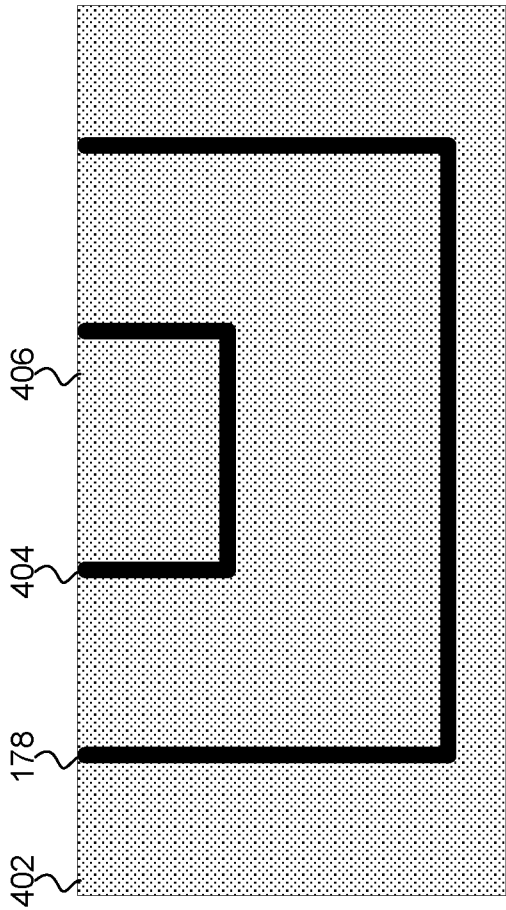


FIG. 4A

400A

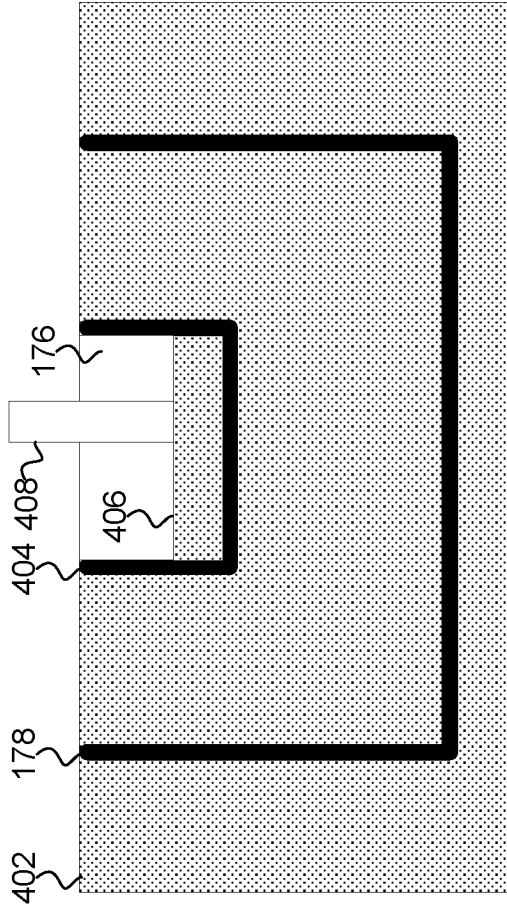
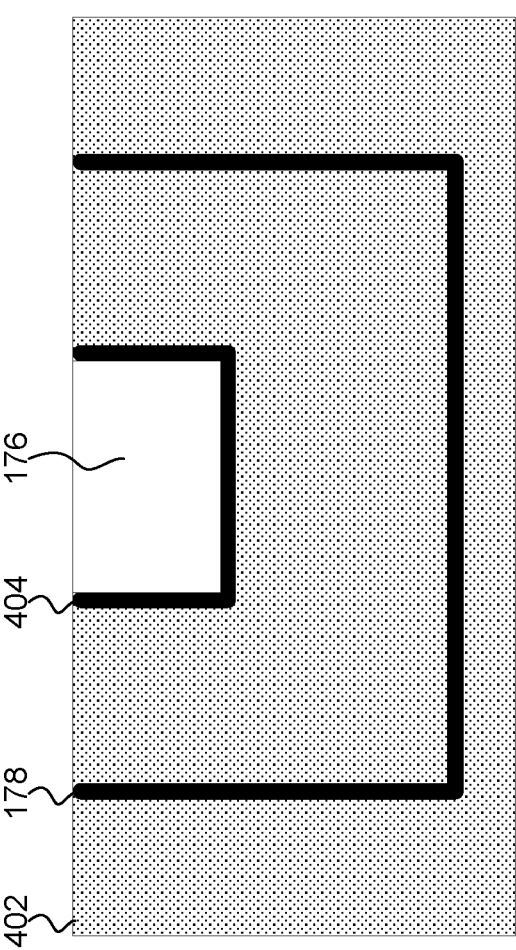


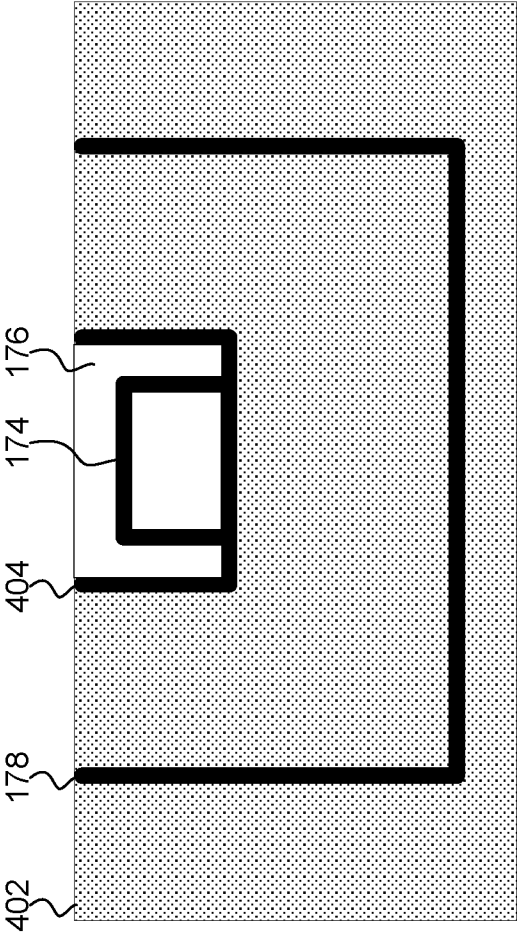
FIG. 4B

400B

400



500A



500B

500

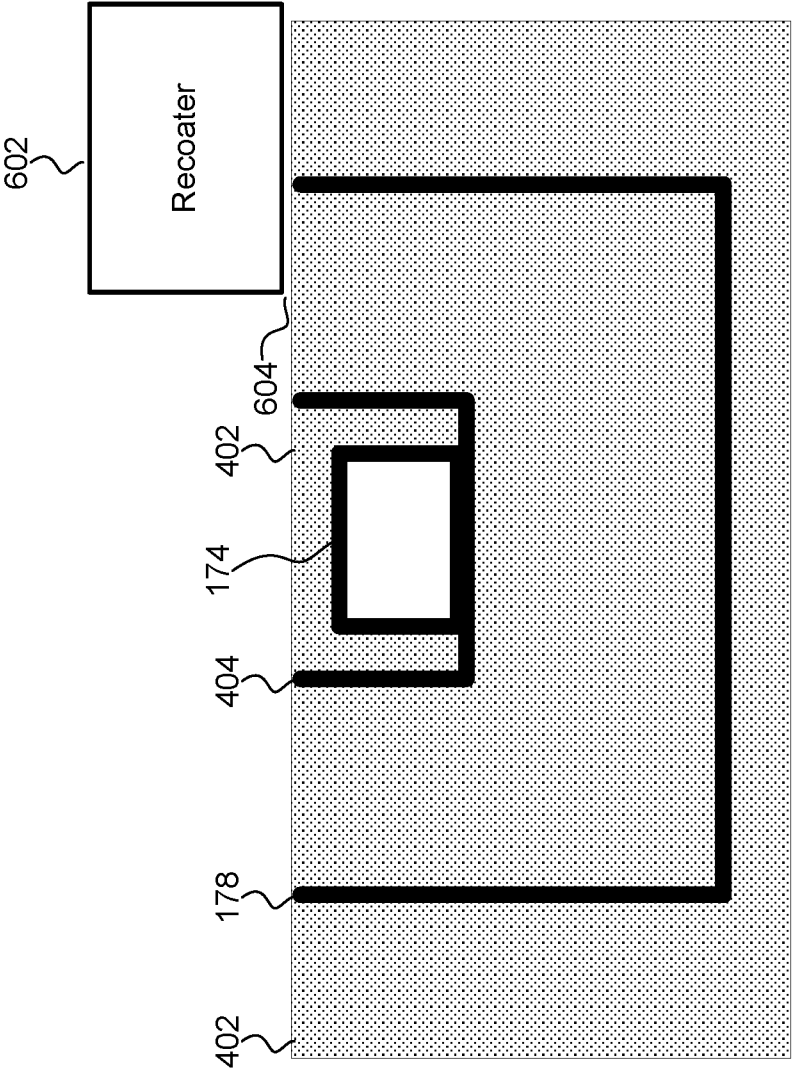


FIG. 6A

600A

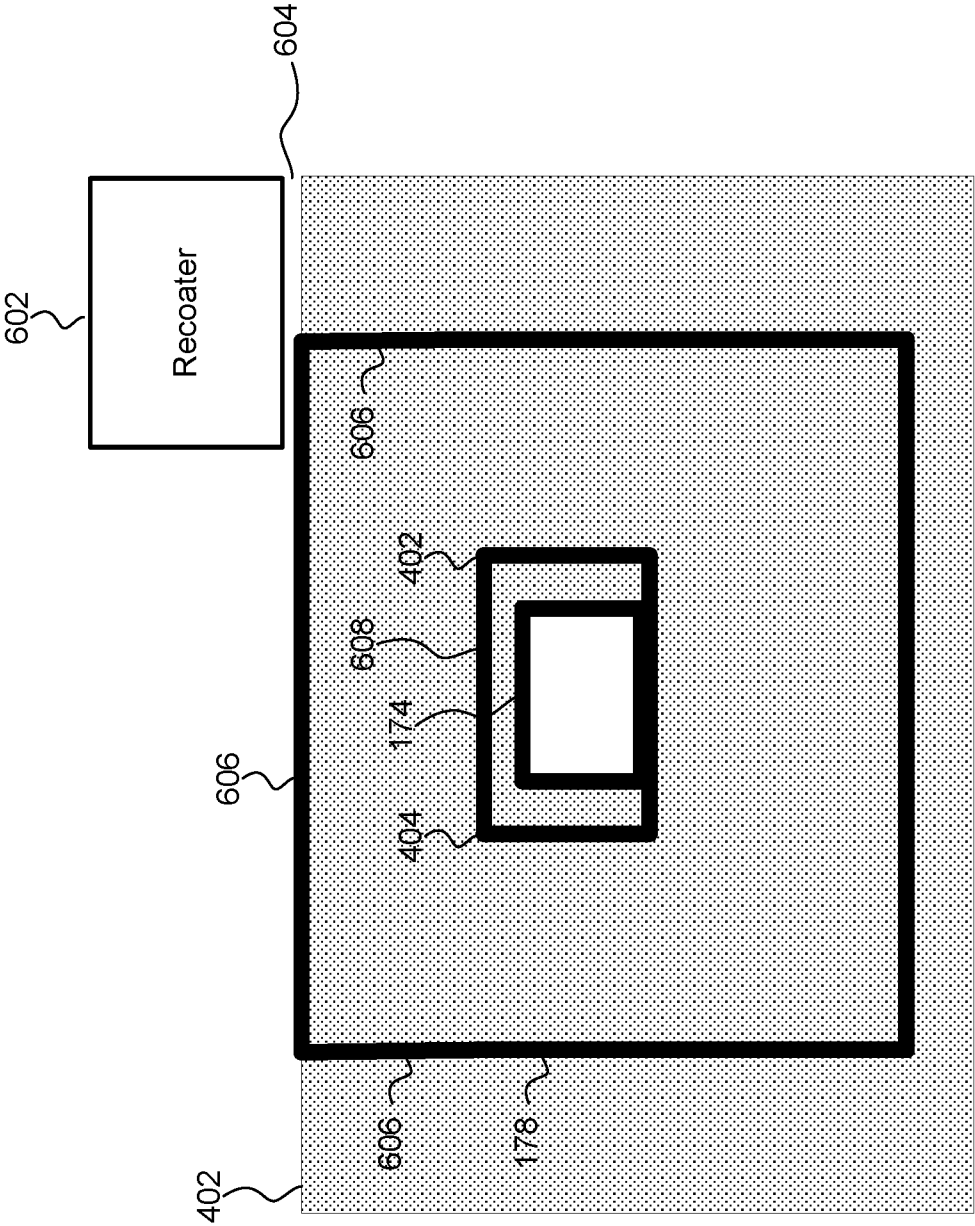


FIG. 6B

600B

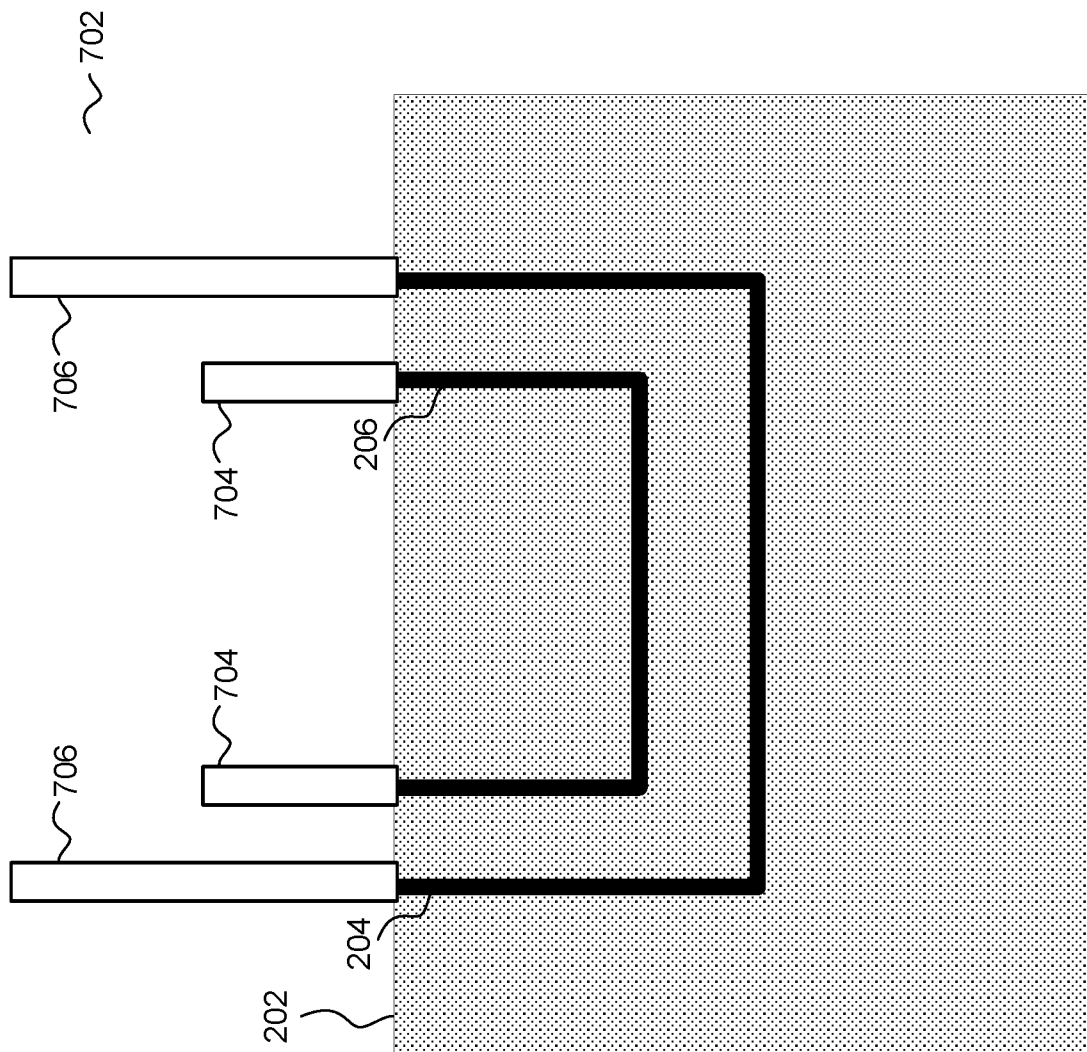


**FIG. 7A**

**700A**

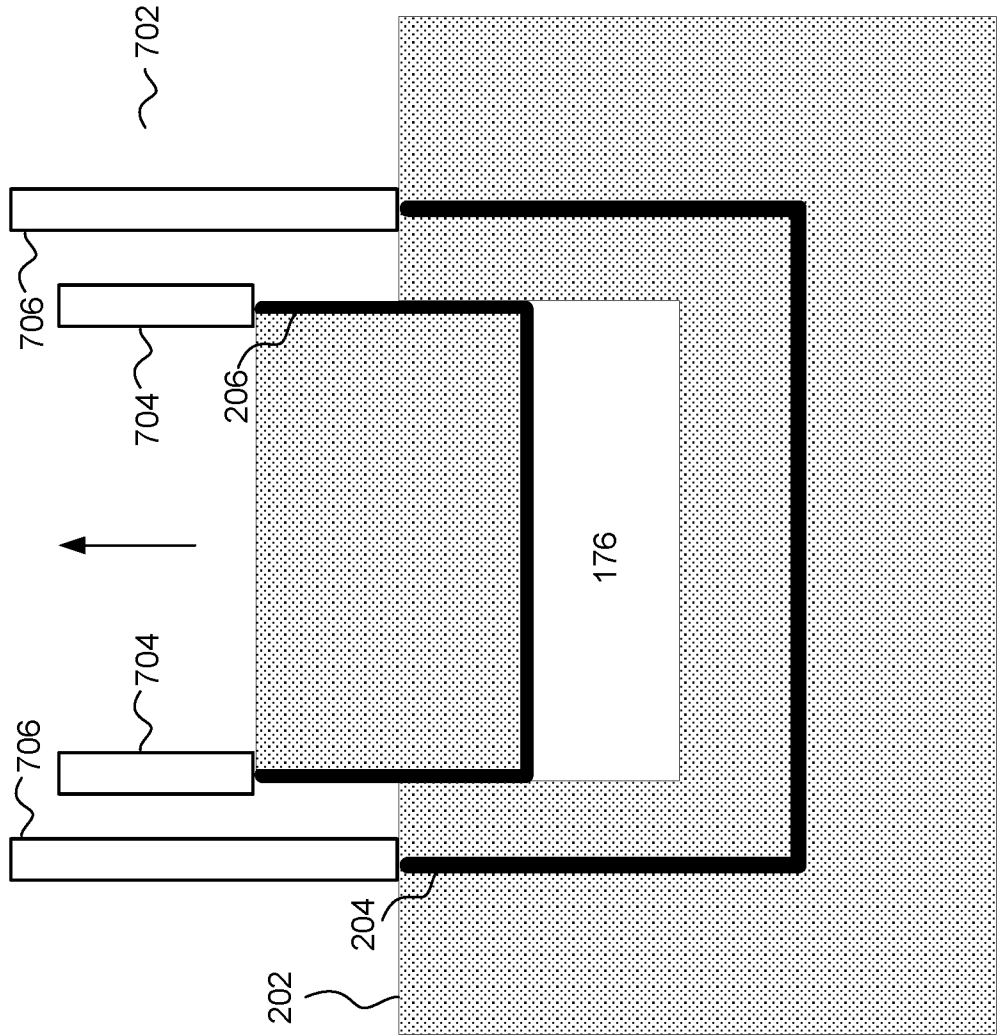


FIG. 7B

700B

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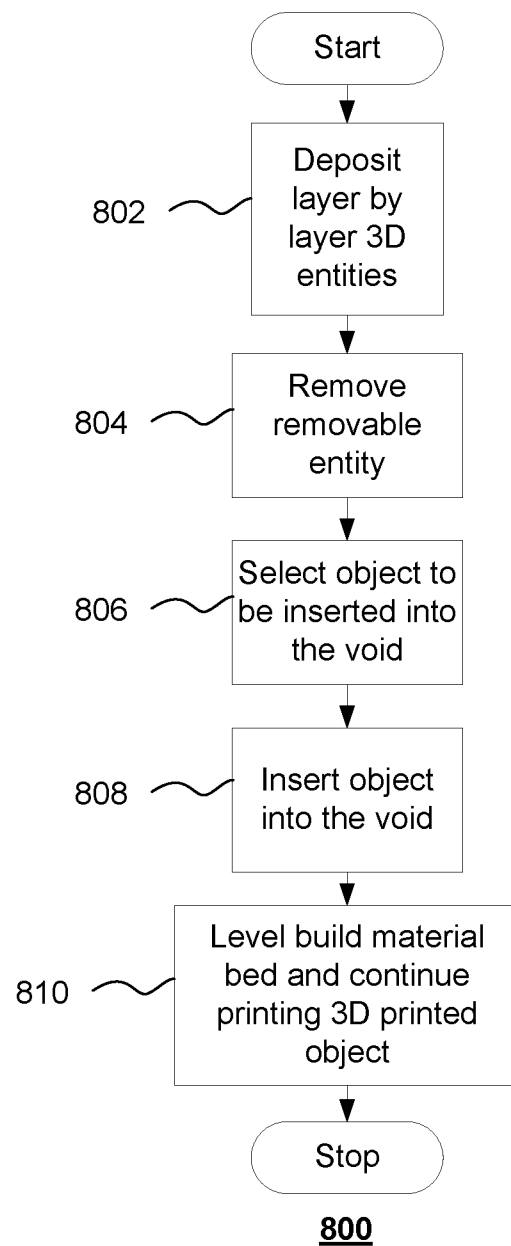


FIG. 8

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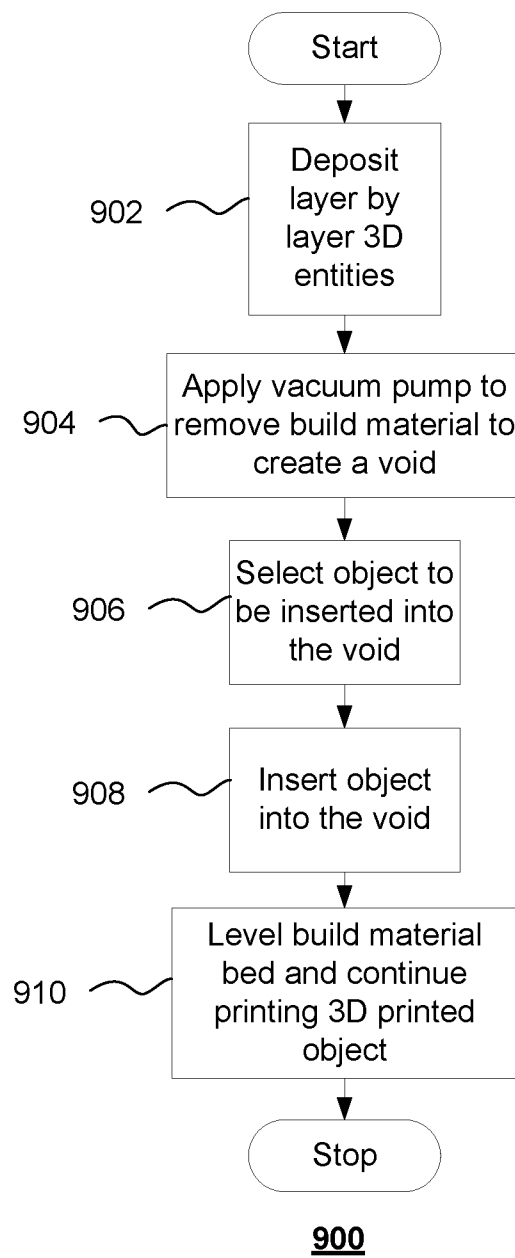


FIG. 9

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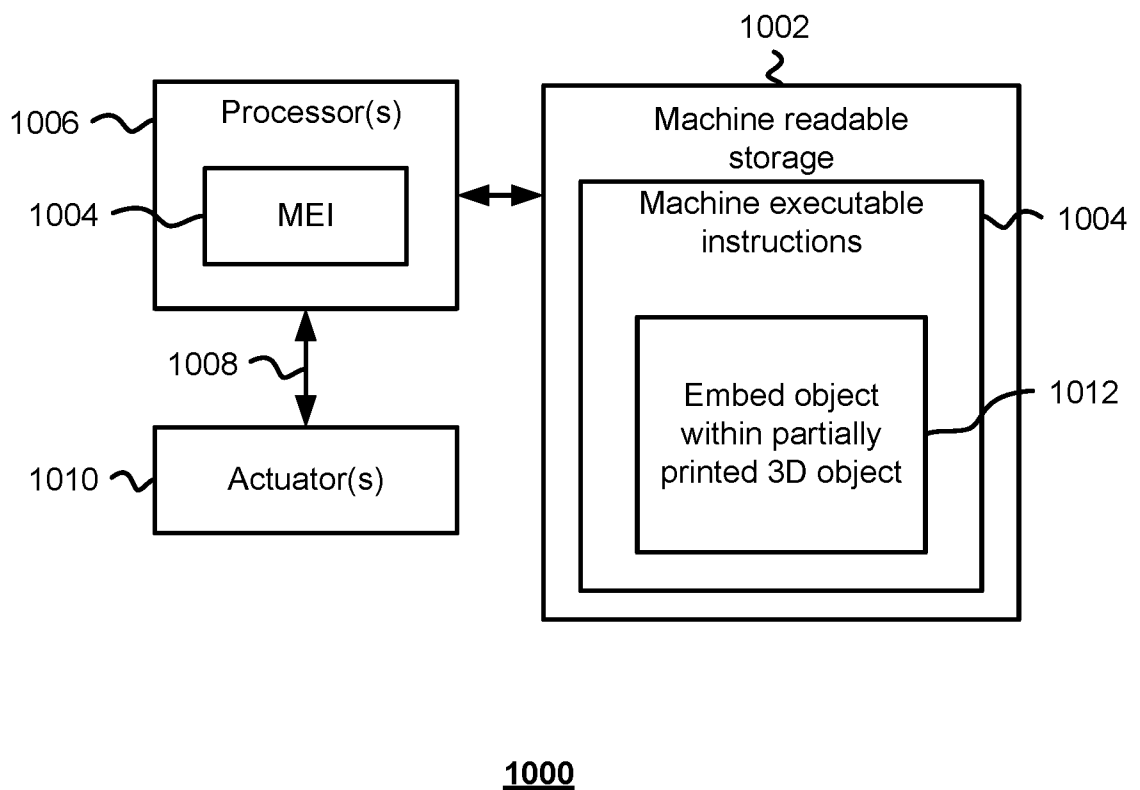
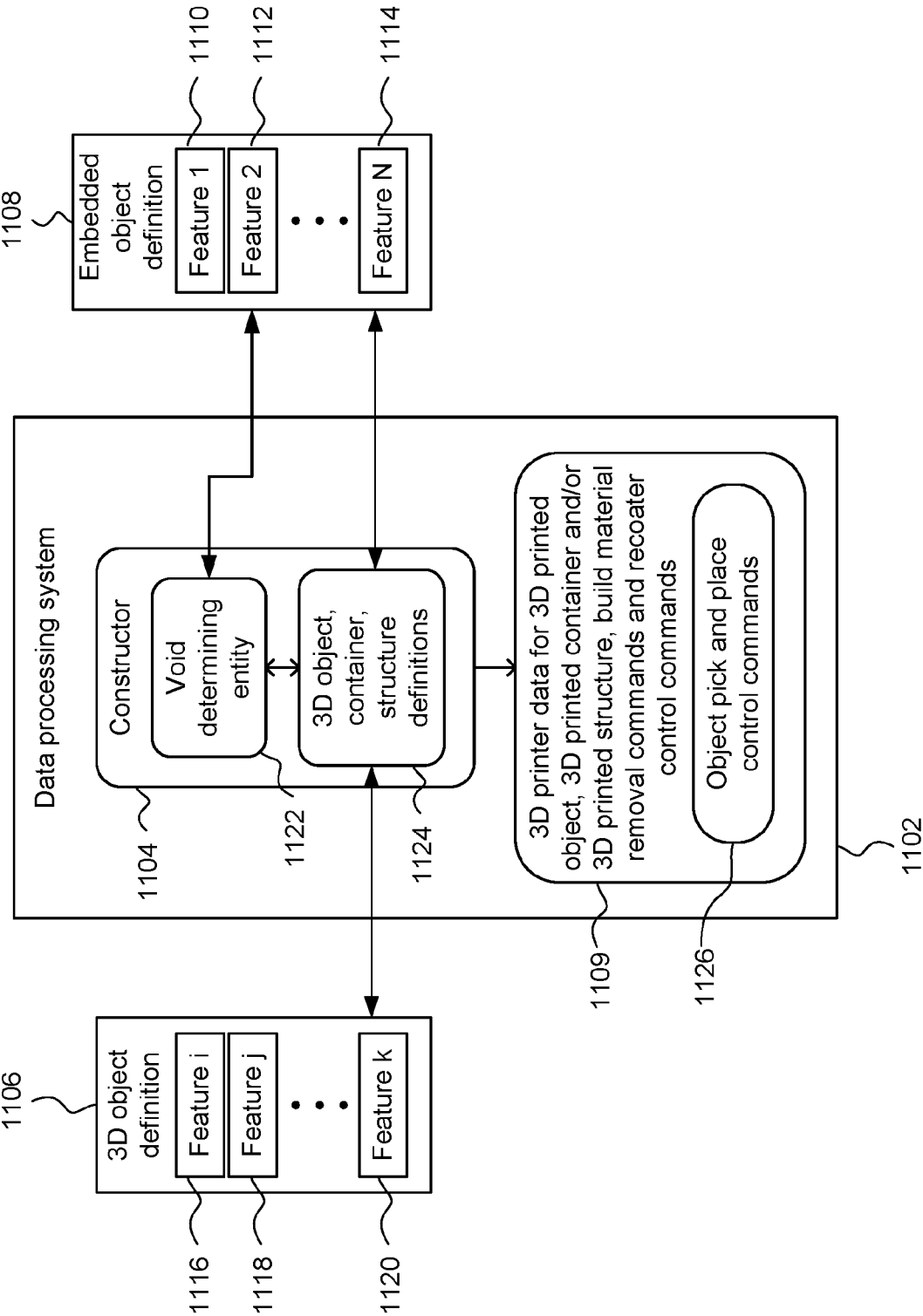


FIG. 10



1100

FIG. 11

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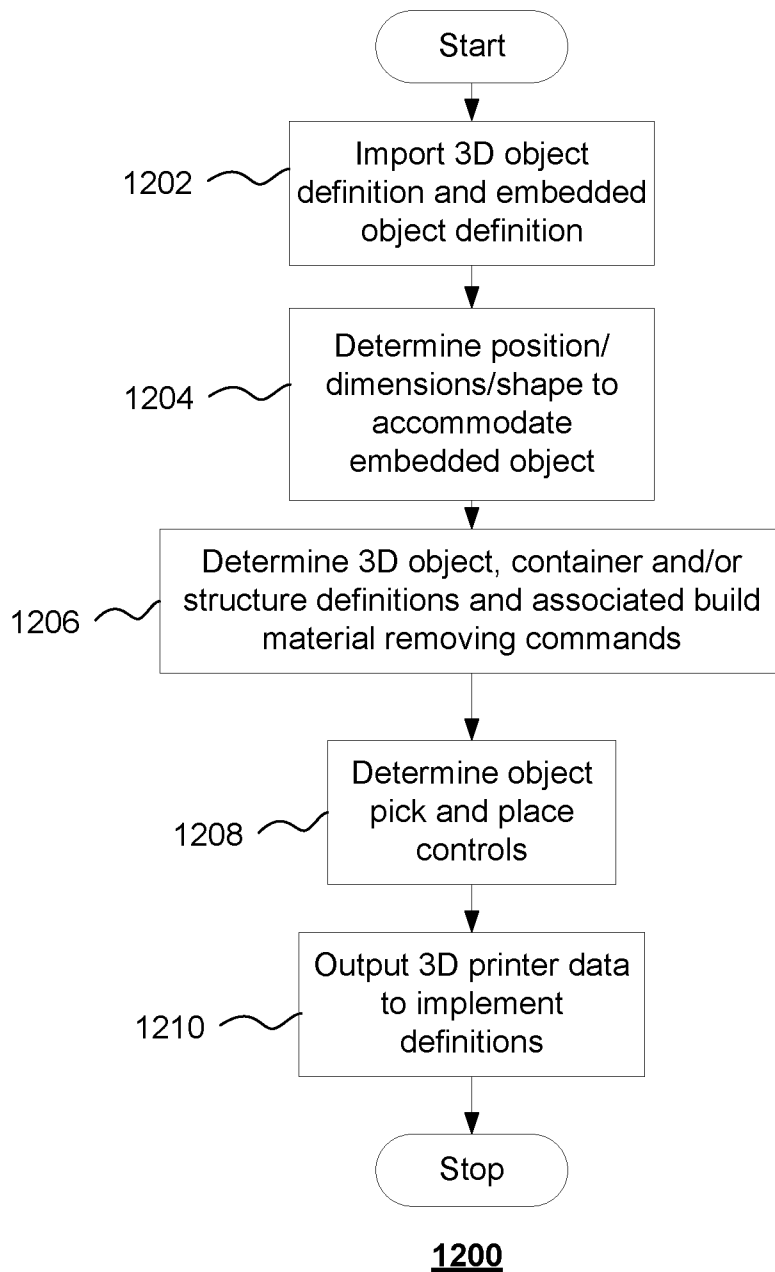


FIG. 12

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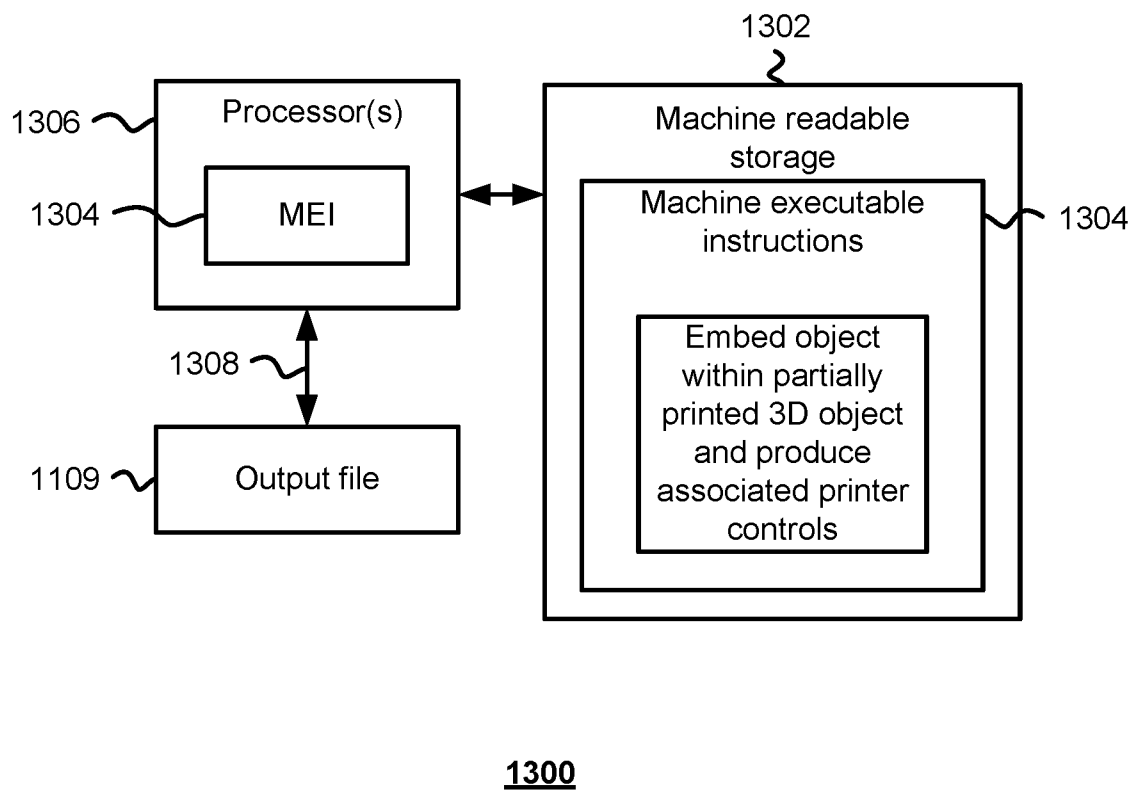


FIG. 13

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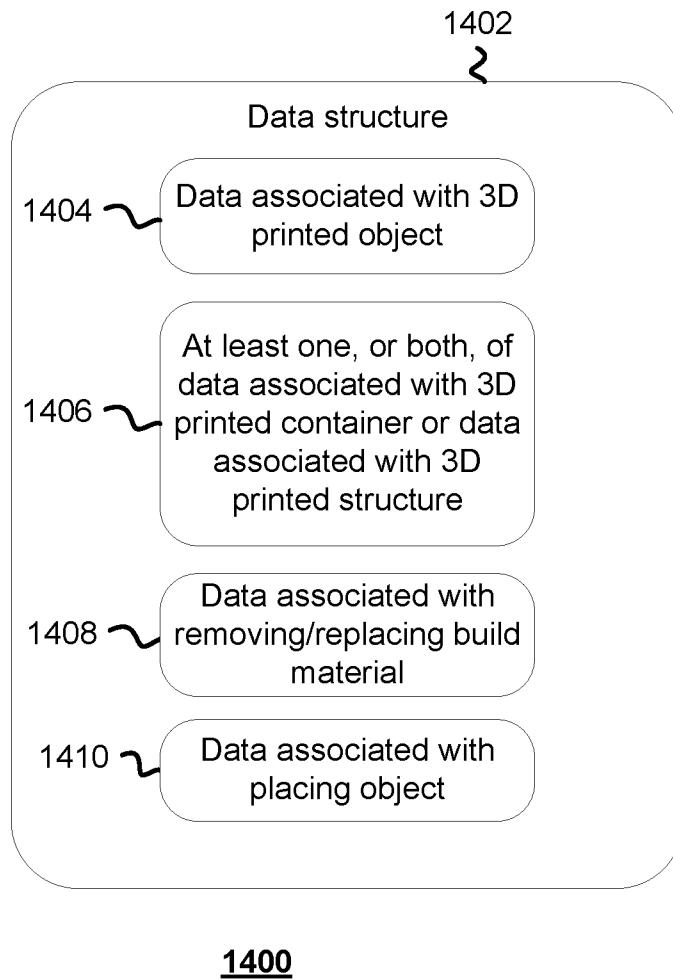


FIG. 14

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 2019/014576

| A. CLASSIFICATION OF SUBJECT MATTER                                                                                                                                                                             |                                                                                                      |                                                                                                                                                                                                                                              |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>B29C 64/10 (2017.01)</b><br><b>B29C 64/20 (2017.01)</b><br><b>B33Y 10/00 (2015.01)</b><br><b>B33Y 30/00 (2015.01)</b>                                                                                        |                                                                                                      |                                                                                                                                                                                                                                              |
| 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 41/00, 41/36, 64/10, 64/20, 67/00, B33Y 10/00, 30/00                                                                                                                                                       |                                                                                                      |                                                                                                                                                                                                                                              |
| 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), USPTO, PAJ, Esp@cenet, DWPI, EAPATIS, PATENTSCOPE, Information Retrieval System of FIPS                                                                                             |                                                                                                      |                                                                                                                                                                                                                                              |
| C. DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                          |                                                                                                      |                                                                                                                                                                                                                                              |
| Category*                                                                                                                                                                                                       | Citation of document, with indication, where appropriate, of the relevant passages                   | Relevant to claim No.                                                                                                                                                                                                                        |
| X                                                                                                                                                                                                               | WO 2017/205375 A1 (VOXEL8 INC) 30.11.2017, Fig.33-36, 41, [0016], [00124], [00224], [00296], [00350] | 1-15                                                                                                                                                                                                                                         |
| A                                                                                                                                                                                                               | US 2013/0141491 A1 (XJET LTD) 06.06.2013                                                             | 1-15                                                                                                                                                                                                                                         |
| A                                                                                                                                                                                                               | US 2011/0199104 A1 (STRATASYS INC) 18.08.2011                                                        | 1-15                                                                                                                                                                                                                                         |
| A                                                                                                                                                                                                               | US 2014/0036035 A1 (MAKERBOT INDUSTRIES LLC) 06.02.2014                                              | 1-15                                                                                                                                                                                                                                         |
| <input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.                                                                           |                                                                                                      |                                                                                                                                                                                                                                              |
| * Special categories of cited documents:                                                                                                                                                                        | “T”                                                                                                  | later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention                                              |
| “A” document defining the general state of the art which is not considered to be of particular relevance                                                                                                        | “X”                                                                                                  | document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone                                                                     |
| “E” earlier document but published on or after the international filing date                                                                                                                                    | “Y”                                                                                                  | document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art |
| “L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)                                         | “&”                                                                                                  | document member of the same patent family                                                                                                                                                                                                    |
| “O” document referring to an oral disclosure, use, exhibition or other means                                                                                                                                    |                                                                                                      |                                                                                                                                                                                                                                              |
| “P” document published prior to the international filing date but later than the priority date claimed                                                                                                          |                                                                                                      |                                                                                                                                                                                                                                              |
| Date of the actual completion of the international search                                                                                                                                                       | Date of mailing of the international search report                                                   |                                                                                                                                                                                                                                              |
| 01 October 2019 (01.10.2019)                                                                                                                                                                                    | 03 October 2019 (03.10.2019)                                                                         |                                                                                                                                                                                                                                              |
| Name and mailing address of the ISA/RU:<br>Federal Institute of Industrial Property,<br>Berezhkovskaya nab., 30-1, Moscow, G-59,<br>GSP-3, Russia, 125993<br>Facsimile No: (8-495) 531-63-18, (8-499) 243-33-37 | Authorized officer<br><br>S. Zhuravlev<br><br>Telephone No. (499) 240-25-91                          |                                                                                                                                                                                                                                              |