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(54) **THREE-DIMENSIONAL PRINTER WITH AN INVERTED CUTTING SURFACE AND A MOVABLE PLATFORM FOR CREATING LAYERED OBJECTS**

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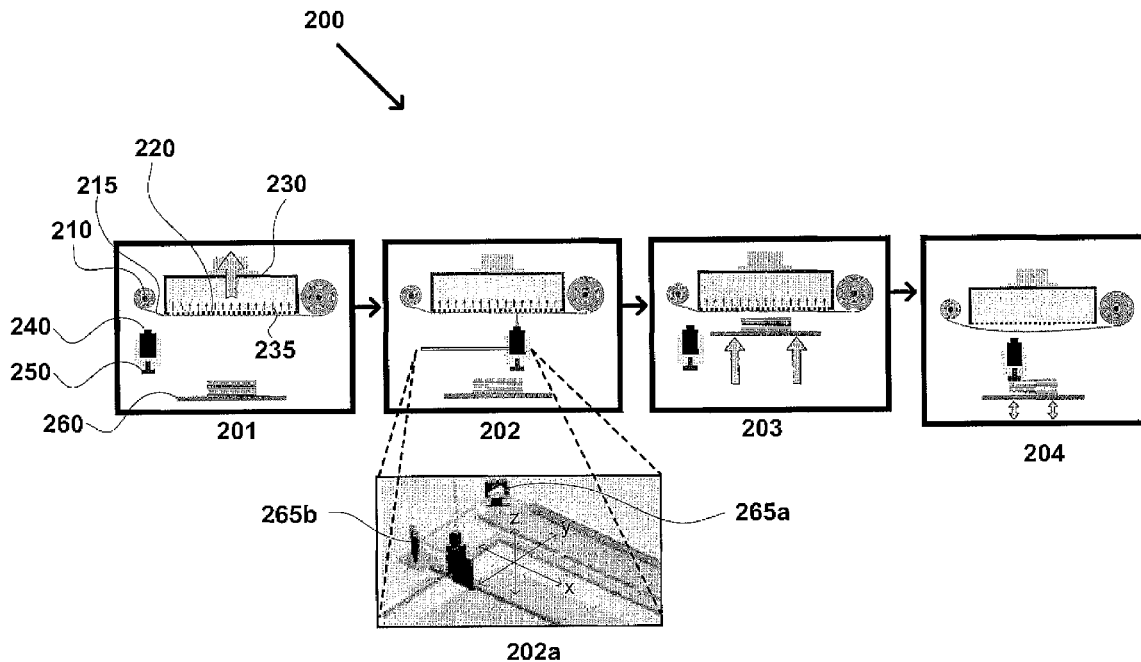
(57) **ABSTRACT**

There is provided a three-dimensional (3D) printer for creating a 3D object using a fabric including a cutting device, an inverted cutting surface, a securing mechanism to secure the fabric against the inverted cutting surface for cutting the fabric by the cutting device into a plurality of layers, a movable platform for receiving each of the plurality of layers, in sequence, from the inverted cutting surface after each layer is cut from the fabric, and a bonding tool to bond each layer of the plurality of fabric layers to a previously received layer as the fabric layers are sequentially received by the movable platform to create the 3D object.

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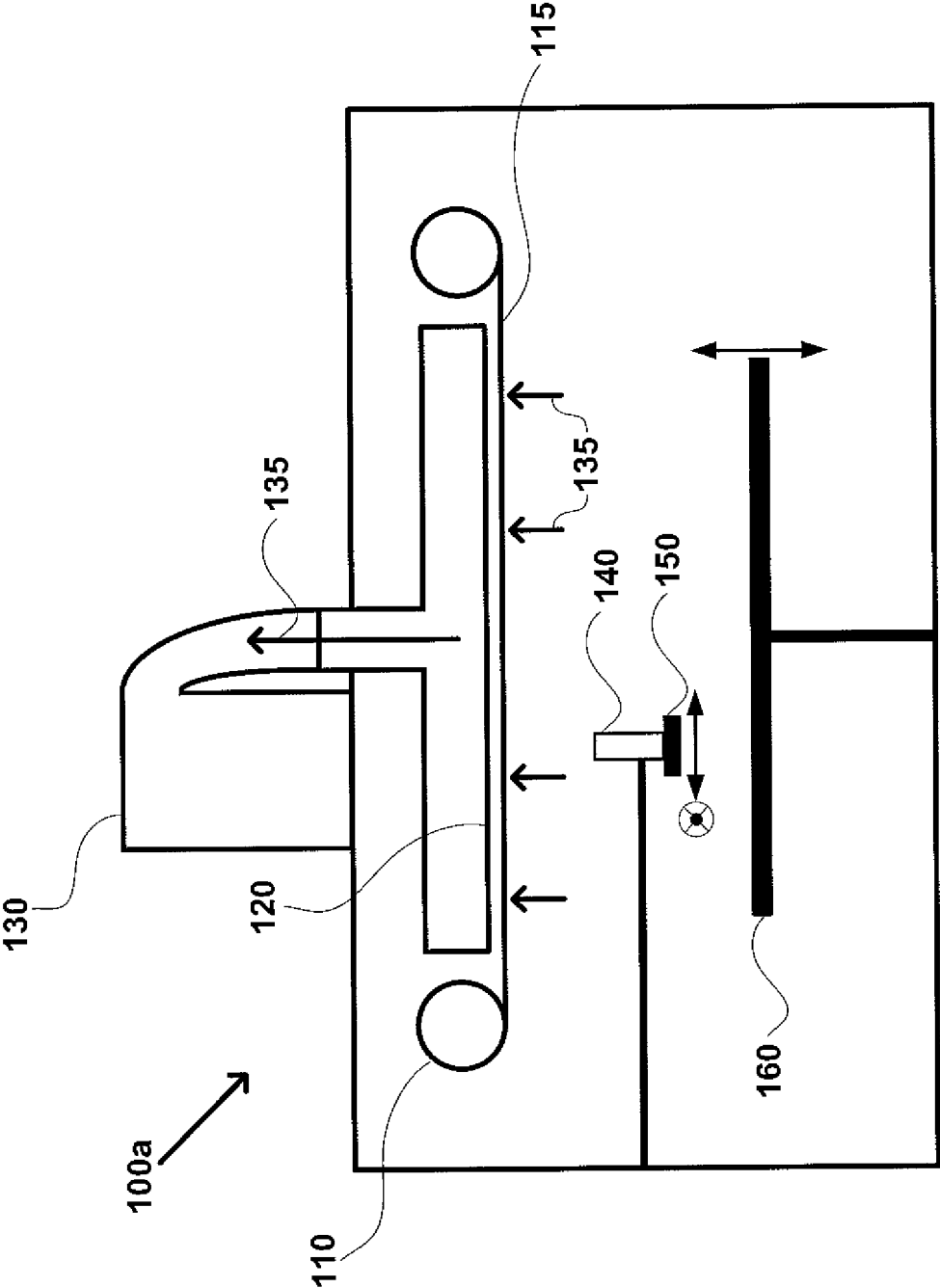


Figure 1a

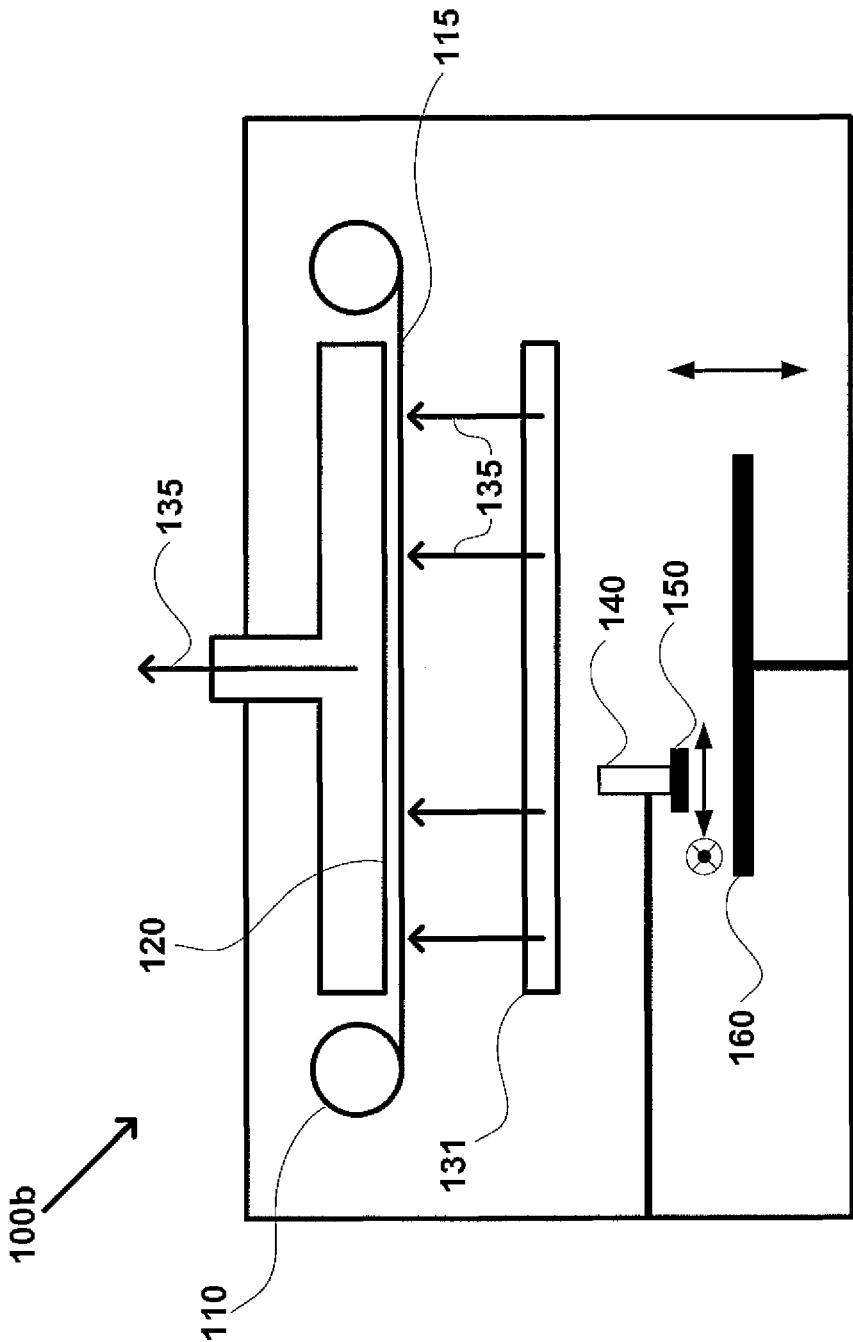


Figure 1b

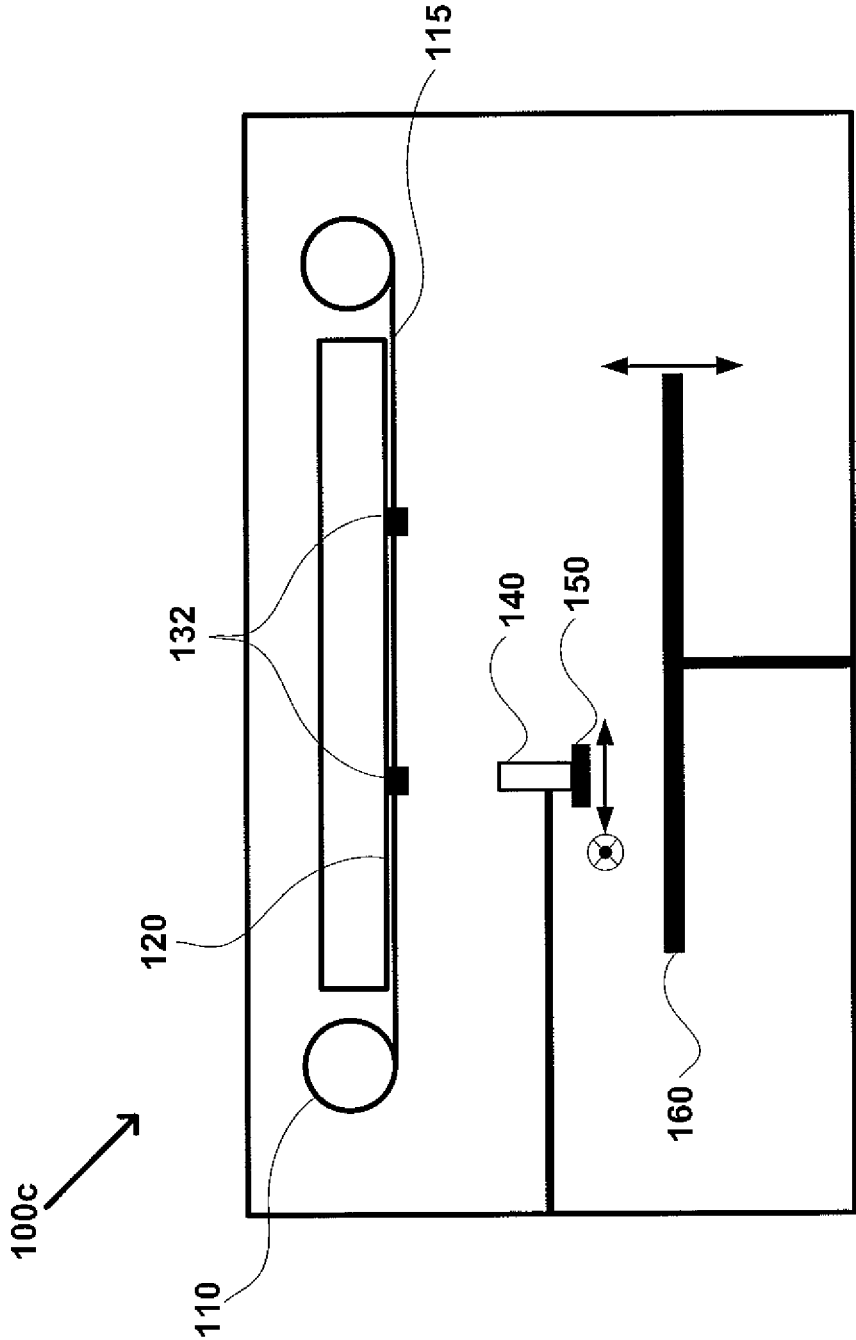


Figure 1c

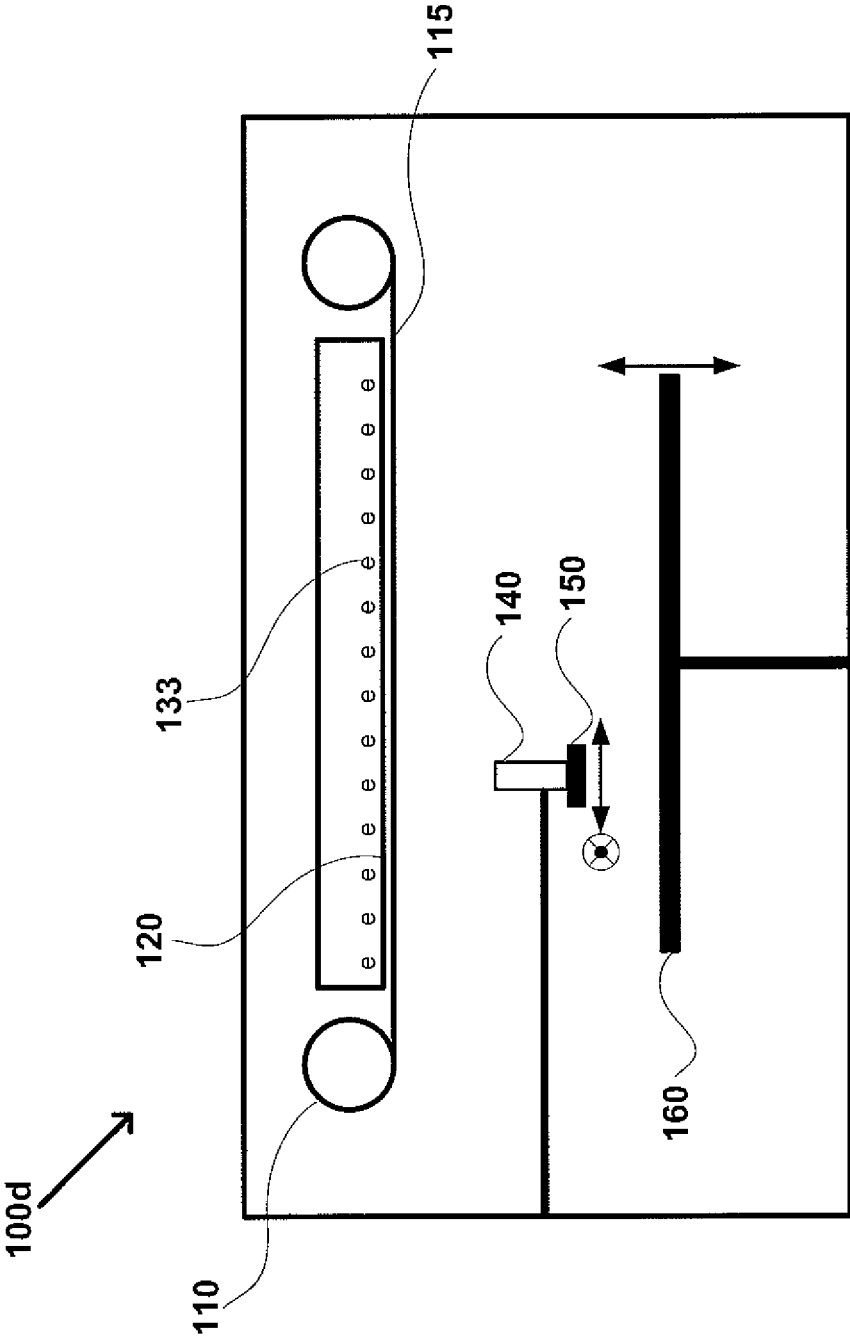


Figure 1d

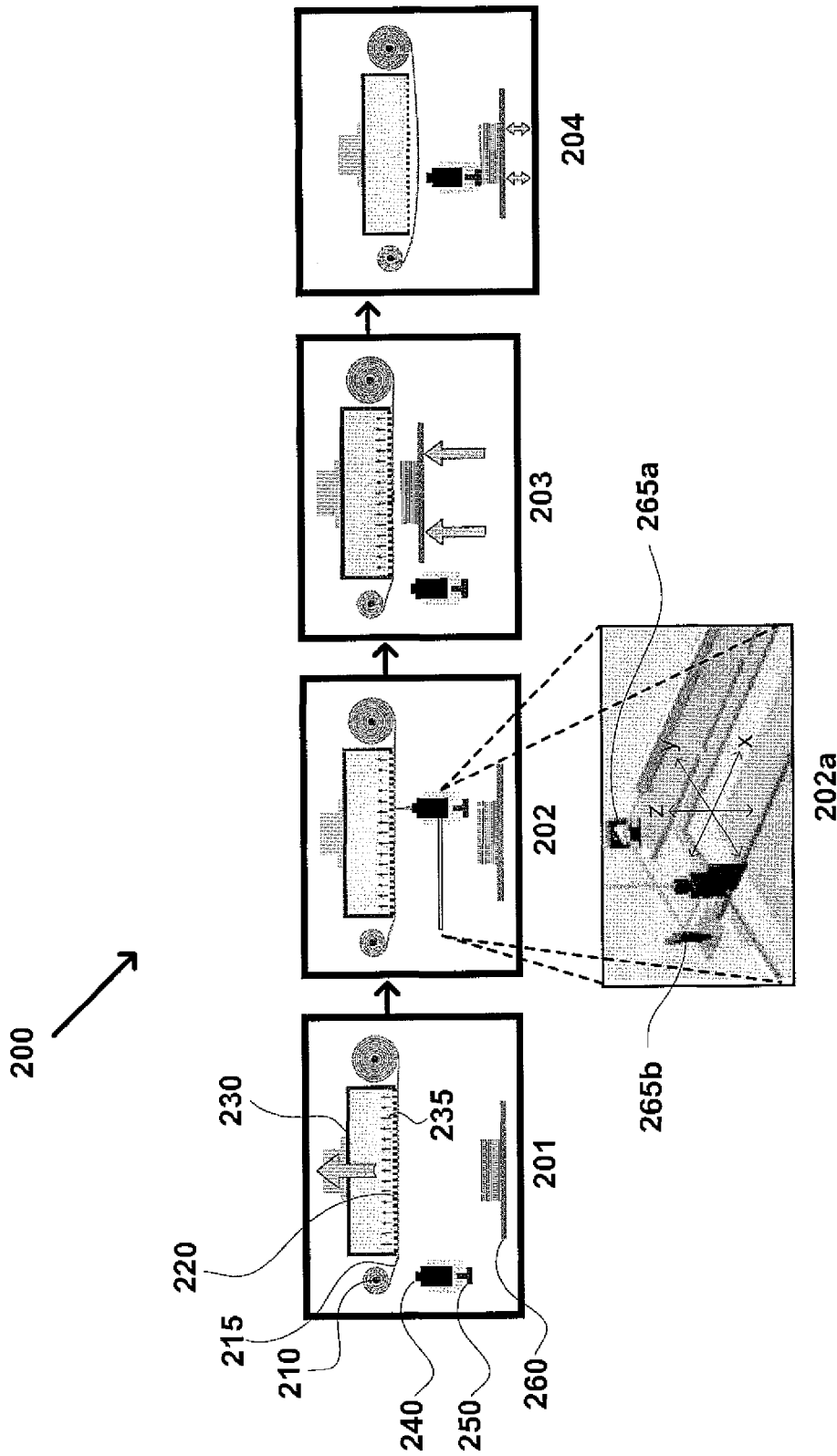


Figure 2

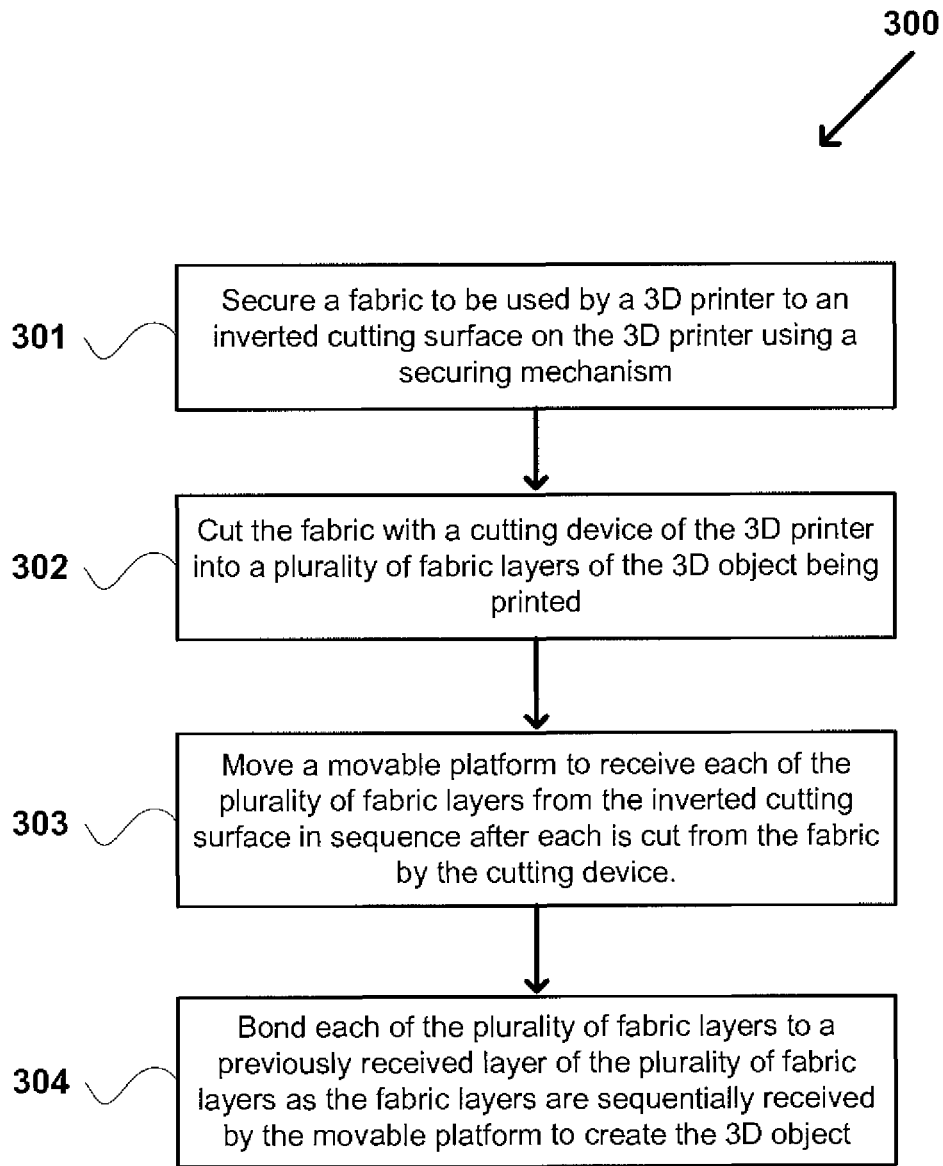


Figure 3

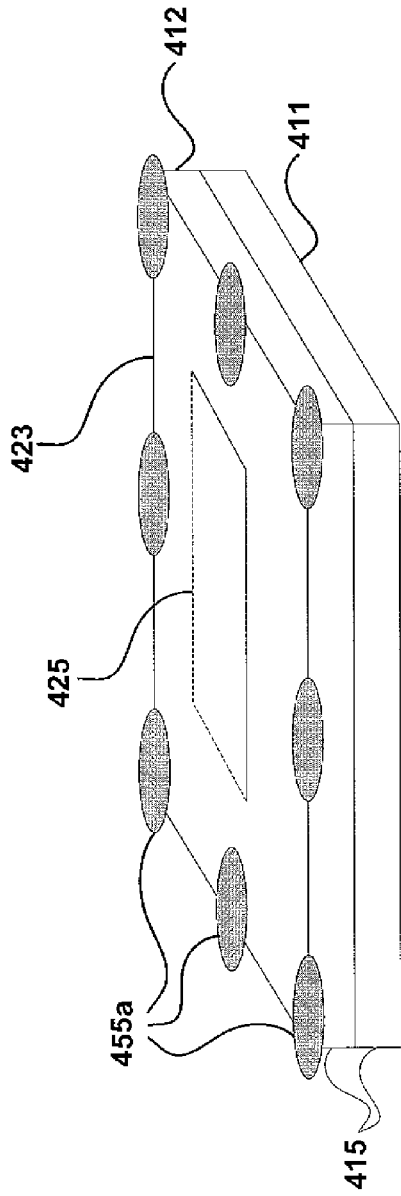


Figure 4a

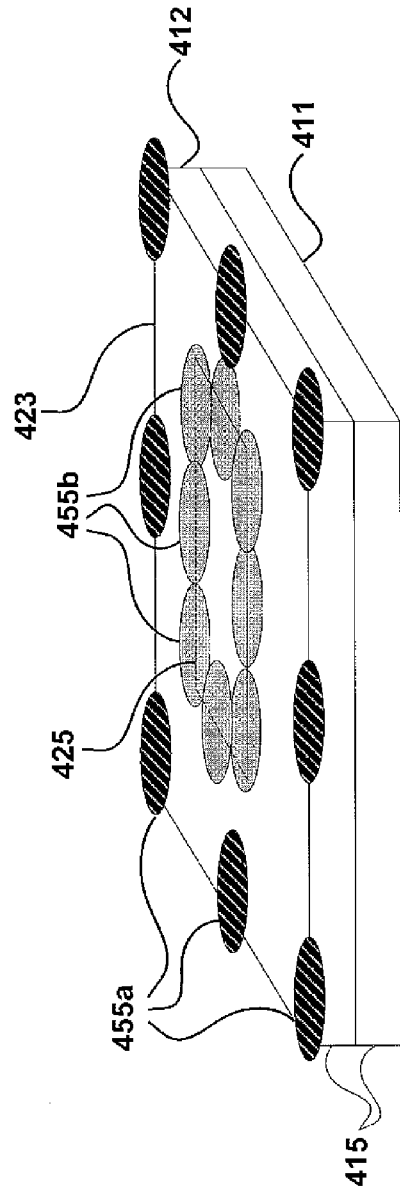


Figure 4b

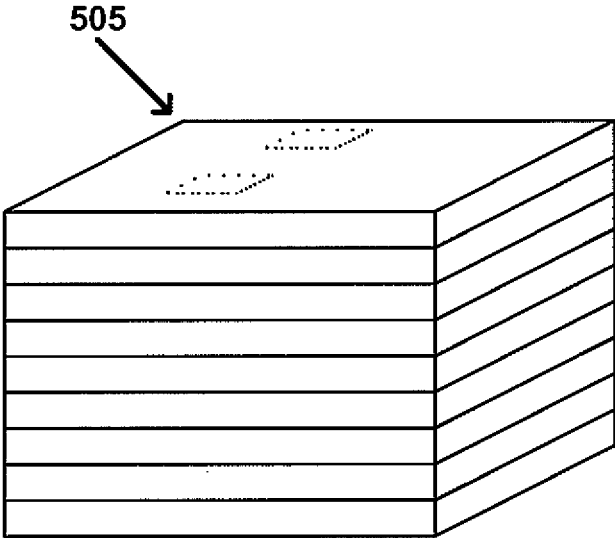


Figure 5a

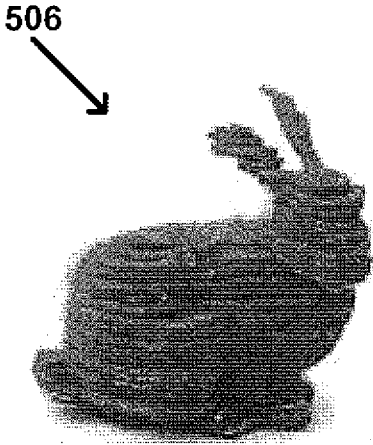


Figure 5b

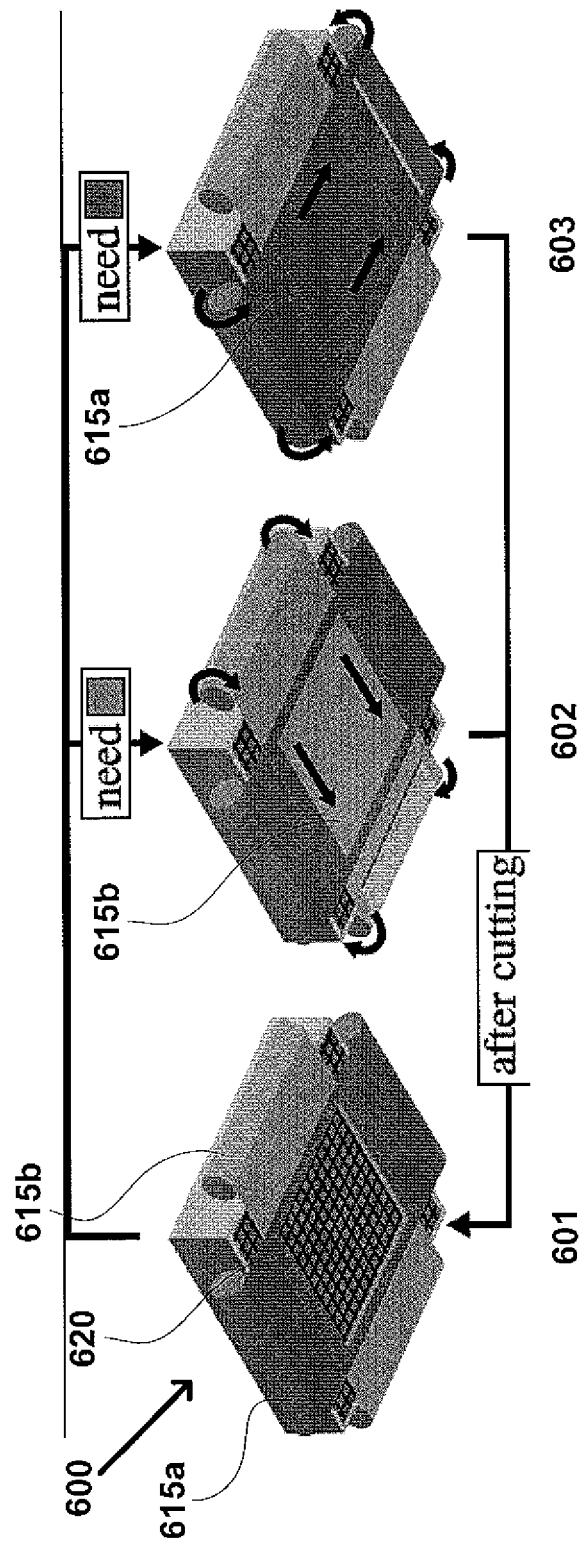


Figure 6

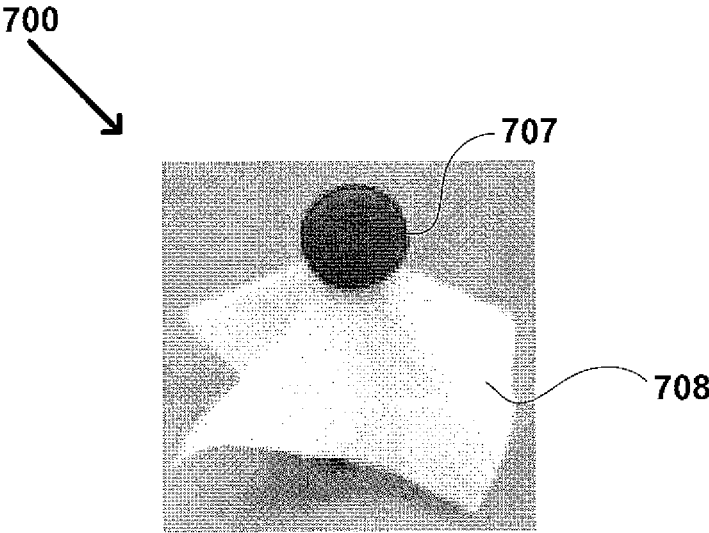


Figure 7

THREE-DIMENSIONAL PRINTER WITH AN INVERTED CUTTING SURFACE AND A MOVABLE PLATFORM FOR CREATING LAYERED OBJECTS

BACKGROUND

[0001] Three-dimensional (3D) printers allow users to manufacture custom objects on demand. Typically, 3D printers work by following a computer's digital instructions to print an object using materials such as plastic, ceramics and metal. The printing process involves building up an object one layer at a time until the printing is complete. Today, more and more 3D printers are being used at homes, and commercial suppliers and retailers to create custom objects.

SUMMARY

[0002] There is provided a 3D printer with an inverted cutting surface and a movable platform for creating layered objects, substantially as shown in and/or described in connection with at least one of the figures, and as set forth more completely in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] FIG. 1*a* shows a diagram of an exemplary 3D printer with an inverted cutting surface and a movable platform, according to one implementation of the present disclosure;

[0004] FIG. 1*b* shows a diagram of an exemplary 3D printer with an inverted cutting surface and a movable platform, according to one implementation of the present disclosure;

[0005] FIG. 1*c* shows a diagram of an exemplary 3D printer with an inverted cutting surface and a movable platform, according to one implementation of the present disclosure;

[0006] FIG. 1*d* shows a diagram of an exemplary 3D printer with an inverted cutting surface and a movable platform, according to one implementation of the present disclosure;

[0007] FIG. 2 shows an exemplary flow diagram of a 3D printing process, according to one implementation of the present disclosure;

[0008] FIG. 3 shows a flowchart illustrating a method of printing a 3D object, according to one implementation of the present disclosure;

[0009] FIG. 4*a* shows a diagram of a step in a bonding process of 3D printing, according to one implementation of the present disclosure;

[0010] FIG. 4*b* shows a diagram of an additional step in a bonding process of 3D printing, according to one implementation of the present disclosure;

[0011] FIG. 5*a* presents a layered 3D object having a surrounding support material and being printed using a 3D printing process, according to one implementation of the present disclosure;

[0012] FIG. 5*b* presents the layered 3D object of FIG. 5*a* after removal of the surrounding support material, according to one implementation of the present disclosure;

[0013] FIG. 6 shows a diagram of a 3D printer using two fabrics for printing a 3D object, according to one implementation of the present disclosure; and

[0014] FIG. 7 shows a layered 3D object printed with a draping layer, according to one implementation of the present disclosure.

DETAILED DESCRIPTION

[0015] The following description contains specific information pertaining to implementations in the present disclosure. One skilled in the art will recognize that the present disclosure may be implemented in a manner different from that specifically discussed herein. The drawings in the present application and their accompanying detailed description are directed to merely exemplary implementations. Unless noted otherwise, like or corresponding elements among the figures may be indicated by like or corresponding reference numerals. Moreover, the drawings and illustrations in the present application are generally not to scale, and are not intended to correspond to actual relative dimensions.

[0016] FIG. 1*a* shows a diagram of an exemplary 3D printer having an inverted cutting surface and a movable platform, according to one implementation of the present disclosure. As shown in FIG. 1*a*, 3D printer 100*a* includes fabric roll 110, fabric 115, inverted cutting surface 120, vacuum 130, as a securing mechanism, cutting device 140, bonding tool 150, and movable platform 160. 3D printer 100*a* may be used to print multi-layered 3D objects using a plurality of layers of fabric 115. As described in more detail below, the 3D object may be printed one layer at a time, with each layer being stacked sequentially on movable platform 160 after the layer is cut, and then bonded to a previously stacked layer. Layers of the 3D object being printed may be cut on inverted cutting surface 120, and assembled by sequentially stacking and bonding the layers on movable platform 160, as discussed in greater detail below.

[0017] Although FIG. 1*a* shows 3D printer 100*a* with fabric roll 110, some implementations may have alternate arrangements for storage of fabric 115. Some implementations may include a mechanism to stack fabric 115, roll fabric 115, and provide a continuous feed of fabric 115. Some implementations may not include a mechanism for storing fabric 115. Fabric may vary from object to object. Some 3D printed fabric objects may benefit from different characteristics of fabric 115. For example, some objects may include a layer that has a draping effect, like a doll that includes a layer that drapes to form the body of the doll, or a doll that includes a layer that drapes to form an item of clothing, such as a shirt or a dress for the doll. Some implementations may benefit from a fabric that is stiffer and may be used to form structural elements of the printed object, such as the ears of a rabbit when the 3D object being printed is a rabbit that does not have floppy ears.

[0018] Fabric 115 may be chosen from any type of fabric, and may be selected for desirable properties of the fabric. Fabric 115 may include fabric made from natural fibers, such as wool, cotton, silk, linen, or other natural fibers. Fabric 115 may include nylon, polyester, acrylic, rayon, spandex, and other synthetic or semi-synthetic fibers. Fabric 115 may include felt, velvet, fleece, and other fabrics that can be made from natural, semi-synthetic, synthetic fibers, or a blend thereof. Still other 3D printed objects may benefit from including more than one fabric. Some implementations may utilize more than one fabric 115. In some implementations, the 3D object being printed may include a layer of conductive fabric.

[0019] In some implementations, a 3D printer may include inverted cutting surface 120. Each layer of the plurality of layers used to create the 3D object being printed may be cut from fabric 115 using inverted cutting surface 120 to support the fabric. In some implementations, inverted cutting surface

120 may be a solid surface typically used for cutting, such as plastic, wood, metal, or other typical cutting surface. However, some implementations may include inverted cutting surface **120** that is air permeable, such as a screen or mesh. For example, when a securing mechanism used to secure fabric against inverted cutting surface **120** includes the use of airflow **135**, such as vacuum **130**, it may be desirable to allow air to flow through inverted cutting surface **120**. In some implementations, inverted cutting surface **120** may be formed using a wire mesh or other material that will provide sufficient support against which secure fabric **115** while fabric **115** is cut by cutting device **140**, and at the same time, allow airflow to pass through fabric **115** and inverted cutting surface **120**. In such an implementation, airflow **135** may provide exhaust for smoke and fumes that may be caused by the cutting process.

[0020] In some implementations, a securing mechanism may include any way that fabric **115** can be secured against inverted cutting surface **120** such that layers can be cut from fabric **115**. In particular, 3D printer **100a** may include vacuum **130** as a securing mechanism to secure fabric **115** against inverted cutting surface **120**. Without a securing mechanism, gravity would cause fabric **115** to fall away from inverted cutting surface **120**. FIG. 1a depicts vacuum **130** arranged to draw air through fabric **115** towards inverted cutting surface **120**. In such an implementation, inverted cutting surface **120** may be air permeable, allowing airflow **135** to flow through fabric **115** and through inverted cutting surface **120**. When airflow **135** is used as securing mechanism, fabric **115** may be secured against inverted cutting surface **120** by the air pressure differential across fabric **115**. As such, vacuum **130** may be disposed on the side of inverted cutting surface **120** pulling air through fabric **115** and inverted cutting surface **120**.

[0021] FIG. 1b shows a diagram of an exemplary 3D printer, according to one implementation of the present disclosure. 3D printer **100b** includes many of the same components as 3D printer **100a**, as indicated by the consistent labels on each component. However, 3D printer **100b** uses fan **131** as a securing mechanism to secure fabric **115** to inverted cutting surface **120**. In some implementations, the securing mechanism may be fan **131** disposed on the same side of inverted cutting surface **120** as fabric **115**, blowing air towards fabric **115**.

[0022] FIG. 1c shows a diagram of an exemplary 3D printer, according to one implementation of the present disclosure. 3D printer **100c** includes many of the same components as 3D printer **100a**, as indicated by the consistent labels on each component. However, 3D printer **100c** shows using clips **132** as a securing mechanism to secure fabric **115** to inverted cutting surface **120**. In some implementations, other securing mechanisms may be used to secure fabric **115** in place against inverted cutting surface **120**. In some implementations, the securing mechanism may include clips or other mechanisms that use pressure or compression to secure fabric **115** against inverted cutting surface **120**. In some implementations, the securing mechanism may include pins, tacks, nails, or other mechanisms that penetrate through fabric **115** to secure fabric **115** against inverted cutting surface **120**.

[0023] FIG. 1d shows a diagram of an exemplary 3D printer, according to one implementation of the present disclosure. 3D printer **100d** includes many of the same components as 3D printer **100a**, as indicated by the consistent labels on each component. However, 3D printer **100d** uses electric charge **133** as a securing mechanism to secure fabric **115** to

inverted cutting surface **120**. In some implementations, the securing mechanism may include various implementations of electromagnetism, such as electric charge, static electricity, or magnetism. FIG. 1d depicts an implementation in which the securing mechanism uses electric charge **133** created by electrons (e) to secure fabric **115** to inverted cutting surface **120**. In some implementations, the securing mechanism may include tension of fabric **115**.

[0024] Cutting device **140** may be used to cut fabric **115** into a plurality of layers, which, in turn, are used to create the 3D object being printed. As shown in FIGS. 1a-1d, inverted cutting surface **120** is located above fabric **115**, which is located above cutting device **140**. Accordingly, cutting device **140** may be utilized to cut fabric **115**, which is above cutting device **140**. Cutting device **140** may include a blade, such as a knife or a razor blade. In some implementations, cutting device **140** may include a heating element. In some implementations, cutting device **140** may include a water jet or a laser. In some implementations, cutting device **140** can be an infrared laser, a near-infrared laser, a visible light laser, or other light cutting device. In some implementations, cutting device **140** may be a water-cooled 40-Watt CO₂ laser tube of the type commonly used in commercial laser cutters to generate a high power infrared laser beam.

[0025] To create the 3D object, layers of the 3D object being printed may be bonded to adjacent layers using bonding tool **150**. Bonding tool **150** may include a heating element. Bonding tool **150**, including the heating element, may be used to activate an adhesive to bond adjacent layers of the 3D object being printed. In some implementations, bonding tool **150** may include a steam nozzle, an iron, or other mechanisms to transfer heat energy for activating an adhesive. In some implementations, an adhesive that is activated by an activation method other than heat, such as radio waves, microwaves, x-rays, may perform the bonding. As such, bonding tool **150** may include a radio device, a microwave device, an x-ray device, or any device that may activate a bonding material used to bond layers.

[0026] Some implementations may include movable platform **160**, which may move relative to inverted cutting surface **120**. Movable platform **160** may move to allow cutting device **140** to make perimeter cuts and border cuts in fabric **115**. Once cutting device **140** has completed making cuts, movable platform **160** may move to receive the layer that has been cut from fabric **115**. Movable platform **160** may sequentially receive each layer that is cut from fabric **115**. In this manner, the 3D object being printed may be formed by a plurality of layers sequentially received by movable platform **160**.

[0027] FIG. 2 shows exemplary flow diagram **200** of a printing process, according to one implementation of the present disclosure. FIG. 3 shows flowchart **300** illustrating a method of printing a 3D object, according to one implementation of the present disclosure, which is described in conjunction with FIG. 2.

[0028] At **301**, here vacuum table **230** acts as a securing mechanism to secure fabric **215** against inverted cutting surface **220**.

[0029] At **302**, cutting device **240** cuts a layer from fabric **215**. To cut a layer from fabric **215**, cutting device **240** may be movable in a first dimension and a second dimension, corresponding to an (X, Y) plane. In some implementations, the first dimension and second dimension may be parallel or substantially parallel to inverted cutting surface **220**. In some

implementations, the first dimension and the second dimension may be within about 0°, 1°, 2°, 3°, 4°, 5°, 10°, 15°, or any combination of the enumerated angles up to about 15°, of variance from parallel to inverted cutting surface 220.

[0030] Cutting device 240 may be capable of cutting at any (X, Y) position corresponding to inverted cutting surface 220. As shown in 202a, a laser tube is arranged along an edge of 3D printer 200. To project the laser to cutting device 240, the beam travels along an edge of the printer in a first dimension by a fixed amount. Moveable mirrors 265a and 265b may be used to control the distance the laser beam travels in the first dimension (along the edge of 3D printer 200) and next in a second dimension (inwards into the printing area). Finally, the beam travels through the laser head, which contains another mirror and a focusing lens, and finally up by a fixed amount in a third dimension, corresponding to a Z dimension, to the fabric. Movable mirrors 265a and 265b may be silicon coated gold reflective mirrors. Note that the second mirror 265b and laser head may be attached to a movable gantry which moves in the first dimension. In addition the laser head can move in the second dimension. Together, these movements can cover the entire (X, Y) cutting plane. Laser intensity may be relatively unaffected when the laser head moves, ensuring a continuous cutting beam without needing to move the large laser tube.

[0031] The process of cutting a layer from fabric 215 involves cutting the perimeter of a bounding shape, and cutting the border of the particular 2D layer being cut. The bounding shape may be the same for each layer of the plurality of layers. In some implementations, the perimeter of the bounding shape may be cut at least two times to ensure that the layer, including the bounding shape, completely separates from fabric 215 and may be easily released onto movable platform 260. To ensure the stability of potentially small pieces that are part of the 2D contour cut by the border of the 2D layer, cutting device 240 may be set to cut almost but not entirely through fabric 215 during the border cut. This ensures a few points with weak connection between the 3D object being printed and the bounding shape. This method ensures that even if border cut creates a piece that is smaller than the grid size of air permeable inverted cutting surface 220, the cut piece will not fall prematurely or be sucked into vacuum table 230 before movable platform 260 arrives. These border cuts are easy to 'finish' during the manual support-removal process simply by tearing away the excess support material of the bounding shape.

[0032] At 303, movable platform 260 may move to receive the layer that was cut by cutting device 250 from fabric 215. Movable platform 260 may be movable in a third dimension. In some implementations, the third dimension may be perpendicular or substantially perpendicular to inverted cutting surface 220. In some implementations, movable platform 260 may be within about 0°, 1°, 2°, 3°, 4°, 5°, 10°, 15°, or any combination of the enumerated angles up to about 15°, of variance from perpendicular to inverted cutting surface 220.

[0033] At 304, bonding tool 250 may be used to bond the just-received 2D layer of the 3D object being printed to a layer previously received by movable platform 260. Bonding tool 250, similar to cutting device 240, may be movable in the first dimension and the second dimension, enabling bonding tool 250 to be positioned at points corresponding to any (X, Y) position of the fabric layer received by movable platform 260.

[0034] FIG. 4a shows a diagram of a step in a bonding process of 3D printing, according to one implementation of

the present disclosure. In some implementations, a fusible adhesive may be incorporated between fabric layers 411 and 412 without being previously adhered to either layer 411 or layer 412. Bonding tool 150, in combination with movable platform 160, may apply heat and pressure to activate the fusible adhesive to bond layer 411 to layer 412. The bonding process begins by bonding points 455a on the perimeter of the bounding shape. In some implementations, the perimeter of the layer may be a rectangle, and the points that are bonded correspond to the corners of the rectangle and the midpoints of each side of the rectangle, as depicted in FIG. 4a.

[0035] FIG. 4b shows a diagram of an additional step in a bonding process of 3D printing, according to one implementation of the present disclosure. After points 455a on perimeter cut 425 of the bounding shape are bonded using bonding tool 160, points 455b, corresponding to points along border cut 423 are bonded using bonding tool 160. FIG. 4b includes points 455a to illustrate that those points were previously bonded, as described in relation to FIG. 4a.

[0036] FIG. 5a shows the completed 3D printed object enclosed within support material provided by the bounding shape, according to one implementation of the present disclosure. FIG. 5b presents the layered 3D object of FIG. 5a after removal of the surrounding support material. FIG. 5b shows a completed printed object, Stanford bunny model 506, after removal of support material, according to one implementation of the present disclosure. Stanford bunny model 506, may be printed with standard printing routine introduced above and consist of 32 layers of acrylic felt fabric resulting in a 64 mm high final product. The printing process disclosed herein may preserve most of the details in the underlying 3D digital model, like the nose and ears, and may include relatively complex overhanging shapes, such as in the ears of Stanford bunny model 506. Because of the cutting strategy used, fabric from the bounding shape of the previous layer serves as support for overhangs, including very small and sharply overhung features such as the ears of Stanford bunny model 506.

[0037] FIG. 6 shows a diagram of a 3D printer including two different fabrics used to print a 3D object, according to one implementation of the present disclosure. As previously mentioned, a 3D printer can be configured to print a 3D object having a plurality of layers of fabric, wherein each layer includes one type of fabric, and different layers of the plurality of layers may include different fabrics. Separate layers of material 615 may be used to create a 3D printed object. Before printing, a "window" the size of the bounding shape may be cut in both materials, corresponding to the perimeter cut of each layer. Then, during printing, only the material to be used in the next layer may be advanced onto the cutting area of inverted cutting surface 620. When the layer is received by movable platform 160, the perimeter of the bounding shape becomes a window in the material, and the process can be repeated, as illustrated in FIG. 6. At 601, 3D printer 600 is ready to begin the process to cut a subsequent fabric layer from either of fabric 615a and fabric 615b. If the next layer of the 3D object being printed requires fabric 615b, fabric 615b is advanced to be cut by cutting device 140, as depicted at 601. However, if the next layer of the 3D being printed requires fabric 615a, fabric 615a is advanced to be cut by cutting device 140, as depicted at 602. As can be seen in FIG. 6, because of the cutting process, specifically that the cutting process cuts not only the border of the 2D layer but also the perimeter of the bounding shape, the cutting area of

inverted cutting surface **620** is left clear for cutting the next layer from either fabric **615a** or fabric **615b**, whichever fabric is needed.

[0038] FIG. 7 shows a layered 3D object printed with a draping layer, according to one implementation of the present disclosure. FIG. 7 shows doll **700** including doll head **707** and draping layer **708**. Doll **700** is a traditional Japanese sunny doll (named *teru teru bozu*) that is usually made with paper or cloth with a round top as the head and draping cloth as the body. An exemplary *teru teru bozu* doll may be printed with the head **707** being printed in red felt and draping layer **708**, forming the body, in white felt. Though printed as a flat square, draping layer **707** may be used to form a body, as shown in FIG. 7.

[0039] In addition to draping, other functional fabrics may be incorporated. For example, a 3D object may be printed which may include a layer of a conductive fabric to create functional objects such as custom printed capacitive touch sensors. Arbitrarily cut shapes within a layer may also be used to create conductive fabric “wiring” between electronic components—the rough equivalent of printed circuit boards, but made entirely from, and embedded inside of, soft fabric. To create functional printed circuits, shorts must be avoided. One approach to accomplishing this is to pause the print and manually remove segments of extra conductive material. It may also be possible to cut conductive traces in a purely automatic fashion without the need to pause the print. This may be accomplished by increasing the width, or kerf, of the laser cut to create a sufficient gap between the intended conductive trace and the material around it. Such small amounts of inner material can be removed by increasing laser power, slowing down movement of the cutting beam, or cutting the path multiple times with a small offset.

[0040] The term two-dimensional (2D), as used herein, refers to a cross-section of a 3D object that is being printed. Each 2D layer may not be literally 2D, but the thickness of the 2D layer may be substantially less than the total height of the finished 3D object, so each layer may be considered a 2D cross section of the 3D object being printed.

[0041] From the above description it is manifest that various techniques can be used for implementing the concepts described in the present application without departing from the scope of those concepts. Moreover, while the concepts have been described with specific reference to certain implementations, a person of ordinary skill in the art would recognize that changes can be made in form and detail without departing from the scope of those concepts. As such, the described implementations are to be considered in all respects as illustrative and not restrictive. It should also be understood that the present application is not limited to the particular implementations described herein, but many rearrangements, modifications, and substitutions are possible without departing from the scope of the present disclosure.

What is claimed is:

1. A three-dimensional (3D) printer for creating a 3D object using a fabric, the 3D printer comprising:

a cutting device;

an inverted cutting surface;

a securing mechanism to secure the fabric against the inverted cutting surface for cutting the fabric by the cutting device into a plurality of fabric layers;

a movable platform to sequentially receive each of the plurality of fabric layers from the inverted cutting surface after each is cut from the fabric by the cutting device; and

a bonding tool configured to bond each of the plurality of fabric layers as sequentially received by the movable platform to a previously received layer of the plurality of fabric layers received by the movable platform to create the 3D object.

2. The system of claim 1, wherein the cutting device is movable in a first dimension and a second dimension, wherein the first dimension and the second dimension are substantially parallel to the inverted cutting surface, and the movable platform is movable in a third dimension, wherein the third dimension is substantially perpendicular to the inverted cutting surface.

3. The system of claim 1, wherein the bonding tool is movable in a first dimension and a second dimension, wherein the first dimension and the second dimension are substantially parallel to the inverted cutting surface, and the movable platform is movable in a third dimension, wherein the third dimension is substantially perpendicular to the inverted cutting surface.

4. The system of claim 1, wherein the fabric is a conductive fabric.

5. The system of claim 1, wherein the cutting device is one of a laser, a knife, and a water jet.

6. The system of claim 1, wherein the inverted cutting surface is an air permeable surface.

7. The system of claim 1, wherein the securing mechanism applies an air pressure differential across the fabric.

8. The system of claim 7, wherein the air pressure differential is created by a vacuum disposed on a side of the inverted cutting surface opposite the fabric, and arranged to secure the fabric to the inverted cutting surface by drawing air through the fabric towards the cutting surface.

9. The system of claim 1, wherein the securing mechanism includes one of static electricity and magnetism.

10. The system of claim 1, wherein the bonding tool includes a heating element.

11. A method for use by a three-dimensional (3D) printer to create a 3D object using a fabric, the method comprising:

securing the fabric against an inverted cutting surface of the 3D printer using a securing mechanism of the 3D printer;

cutting the fabric using a cutting device of the 3D printer into a plurality of fabric layers, after the securing of the fabric against the inverted cutting surface;

moving a movable platform to sequentially receive each of the plurality of fabric layers from the inverted cutting surface after each is cut from the fabric by the cutting device; and

bonding each of the plurality of fabric layers as sequentially received by the movable platform to a previously received layer of the plurality of fabric layers received by the movable platform to create the 3D object.

12. The method of claim 11 further comprising:

moving the cutting device in a first dimension and the second dimension, wherein the first dimension and second dimension are substantially parallel to the inverted cutting surface; and

moving the movable platform in a third dimension, wherein the third dimension is substantially perpendicular to the inverted cutting surface.

- 13.** The method of claim **11** further comprising:
moving the bonding tool in a first dimension and the second dimension, wherein the first dimension and second dimension are substantially parallel to the inverted cutting surface; and
moving the movable platform in a third dimension, wherein the third dimension is substantially perpendicular to the inverted cutting surface.
- 14.** The method of claim **11**, wherein the fabric is a conductive fabric.
- 15.** The method of claim **11**, wherein the cutting device is one of a laser, a knife, and a water jet.
- 16.** The method of claim **11**, wherein the inverted cutting surface is an air permeable surface.
- 17.** The method of claim **11**, wherein the securing applies an air pressure differential across the fabric.
- 18.** The method of claim **17** further comprising:
creating the air pressure differential using a vacuum disposed on a side of the inverted cutting surface opposite the fabric, and arranged to secure the fabric to the inverted cutting surface by drawing air through the fabric towards the cutting surface.
- 19.** The method of claim **11**, wherein the securing uses one of static electricity and magnetism.
- 20.** The method of claim **11**, wherein the bonding uses a heating element.

* * * * *