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OBJECT SUPPORT DURING 3D PRINTING OF AN OBJECT BASED ON A MODEL

(57)

The present disclosure relates to method of supporting on support elements during 3D printing of a 3D print object based on a 3D print model, comprising:

- providing the model;
- displaying a visual representation of the model in which faces of the visual representation are selectable by a user; and
- receiving input from the user on a selection of at least one of the faces of the visual representation of the model with respect to at least one of addition of support elements and orientation of the object to be printed during 3D printing;
- generating an extended version of the model with support elements added thereto, based on the received input from the user with respect to the at least one of addition of support elements and orientation of the object to be printed during 3D printing; and
- 3D printing the extended version of the model.

OBJECT SUPPORT DURING 3D PRINTING OF AN OBJECT BASED ON A MODEL

The present disclosure relates to a method of supporting on support elements during 3D printing of a 3D print object based on a 3D print model, comprising: providing the model; and driving a 3D printer to print the object to be printed. The present disclosure also relates to a program to be stored on a record carrier and a 3D printer performing the method.

To the best knowledge of the inventors of the present disclosure, all known 3D printers and methods associated therewith, when an object to be printed in a 3D printer is to be linked to a build platform, arrange the object on support elements or posts, connecting the object to be printed during 3D printing to the build platform. After 3D printing, the 3D printed objects are broken from the supports or posts, leaving visible marks of where the posts were connected to the object during printing, even when the support elements or posts have a shape converging towards the object to minimize the break area and the visual effects thereof. From a position of 3D printer manufacturers, this disadvantage of scarring 3D printed objects by breaking the 3D printed objects off the support elements or posts, has to date not been acknowledged or at least not been addressed, since the choice of faces or surfaces on which the scarring effect is to be minimized is subjective, where a user of a 3D printer may at one time wish to prevent scarring of one face or surface of the object, and another face or surface at another time. For such reasons, 3D printer manufacturers have either not acknowledged such issues with their prior 3D printers, or elected to focus arrangement of support elements or posts based on structural and more objective considerations, to provide for sturdy and good support of the object during 3D printing.

However, the inventors of the present disclosure have found a solution to service the needs of the users, concerning leaving faces or surfaces as unscarred as possible, while still also providing a good and sturdy printing support. To this end the present disclosure discloses a method of supporting on support elements during 3D printing of a 3D print object based on a 3D print model, comprising: providing the model; displaying a visual representation of the model in which faces of the visual representation are selectable by a user; and receiving input from the user on a selection of at least one of the faces of the visual representation of the model with respect to at least one of addition of support elements and orientation of the object to be printed during 3D printing; generating an extended version of the model with support elements added thereto, based on the received input from the user with respect to the at least one of addition of support elements and orientation of the object to be printed during 3D printing; and 3D printing the extended version of the model.

Consequently, the user's input is taken into account when orienting the model relative to for example a reference, such as a build platform, for printing selected faces or surfaces with as

little scarring as possible, while maintaining a good and sturdy support on posts of the object during printing on faces or surfaces, in relation to which a user attributes less importance regarding scarring thereof.

Following the above reference to the gist of the present disclosure in terms and expressions of the appended independent method claim, it is to be noted that a diversity of preferred embodiments is defined in the appended dependent method claims, and/or will become apparent from the below embodiment description.

In a potential preferred embodiment, the method further comprises receiving input from the user on movement comprising at least one of translation and rotation of the visual representation of the model, prior to receiving input from the user on the selection of at least one of the faces of the visual representation of the model with respect to addition of support elements.

In a potential preferred additional or alternative embodiment, the method further comprises receiving input from the user on orientation of the object including at least one of translation and rotation of the object during 3D printing, prior to 3D printing, and orienting the extended version of the model during 3D printing based on the received input from the user on the orientation of the object.

In a potential preferred additional or alternative embodiment, the method further comprises orienting the extended version of the model with support elements added thereto for 3D printing, based on the received input from the user with respect to addition of support elements. In such an embodiment the method may comprise orienting the extended version of the model with support elements added thereto for 3D printing of the object relative to a print platform of a 3D printer, from which platform the support elements extend to support the object to be printed. Additionally to or as an alternative for orienting the extended version of the model, the method may comprise: attributing weight factors to the faces based on surface areas of the faces; multiplying orientations of the faces with the corresponding weight factors; averaging normalized bi-rotational axes of the faces; and by adaptation of the orientation, generating an optimized orientation of the model for printing of the object to be printed, which is optimized in relation to the user input with respect to at least the addition of support elements. Additionally or alternatively, the method may comprise: display to the user of the oriented extended version of the model; receiving input from the user on movement comprising at least one of translation and rotation of the oriented extended version of the model within limits to avoid supports at a face selected not to be supported; and adapting the oriented extended version of the model to received input from the user on movement comprising at least one of translation and rotation of the oriented extended version of the model.

In a potential preferred additional or alternative embodiment, generating an extended version of the model with support elements added thereto may comprise: slicing the model; converting features of each slice into at least one of polygons and vectors at locations of the faces;

determining at least one point of the model corresponding to a point of the object to be printed closest to a 3D printing platform of a 3D printer. In such an embodiment, the method according to the present disclosure may further comprise: from a slice comprising the point of the model corresponding to a point of the object to be printed closest to a 3D printing platform of a 3D printer, determining directional overhang of subsequent slices by comparing a current layer with a previous layer closer to the build platform, taking the point of the model corresponding to a point of the object to be printed closest to the 3D printing platform of the 3D printer as the origin; and comparing the current layer with the previous layer, and, if the area thereof is larger than the area of the previous layer, it is determined that there is overhang, and when overhang through subsequent slices reaches a predetermined value, arranging a support element in the extended version of the model. Then, the method may further comprise placement of support elements only outside of the periphery of previously placed supports and in slices above the at least one point of the model corresponding to a point of the object to be printed closest to a 3D printing platform of a 3D printer, according to predefined support element patterns.

It is noted here that the present disclosure not only relates to a method, but also to a computer or a 3D printer having a processor and a memory, wherein the memory comprises a program configured to enable the 3D printer to execute the steps of the above method, as well as a record carrier, storing a computer program to enable a computer or a 3D printer, when the computer program is loaded therein, to execute the steps of the above method. In this respect it is noted that the method may be implemented on a separate computer, to provide the outcome to a 3D printer for 3D printing of objects. For example, calculation power required may better be suited for a separate computer than a 3D printer. In such a case the computer separate from the 3D printer is to be considered as a component of or addition to the 3D printer, encompassed by the relevant ones of the appended independent claims.

As a side consideration, it is noted that performing the method on a component of or addition to the 3D printer has advantages in terms of data transfer. 3D models can be extremely large. However, when performing the method on the separate component or additional computer, only slices need to be transmitted together with depth (Z-axis) drive information, where the slices comprise binary information of where and where not to print the object over the cross sectional slices thereof. In this sense the slices can be considered as black-and-white representations of cross sections / slices of objects to be printed, indicating where to print, and where not to. This enables a considerable reduction in data volumes, where only these slices and the depth (Z-axis) drive information need to be sent to the 3D printer.

Before proceeding with the below embodiment description of the appended drawing, reference is made to a number of challenges and solution strategies regarding these challenges,

relative to prior 3D printing techniques, in terms of the novel approach to preparing a model for printing and provide (the) correct (type of) support elements or posts.

As a first challenge it is noted that considerable expertise is required to place the support elements or posts on a correct location to support the model properly. As a second challenge it is noted that considerable expertise is required to give the supports each the right shape in order to support the model properly and not waste (a lot of) material through trial and more pertinently: error.

If the model is not supported properly with the right type of supports, the print job will fail and material will be wasted, and for larger objects to be printed or using sparse printing material this would result in considerable loss of much material or a little expensive material.

The present disclosure automates the placing and potentially also shaping of supports.

The process works as follows. A model is provided, for example by loading it into the 3D printer system. The user can choose if the model is to be laid flat and – if so - in what orientation, or if it needs to be auto orientated by the 3D printer.

The user selects which faces are important, this selection method can be used for either selecting the faces on which to lay the model flat or which faces that should be excluded from supports or – to the contrary - should have supports. This way, the inventors of the present disclosure have adopted a novel manner of looking at 3D printing from the perspective of where not to place supports instead of looking where to place supports.

The adopted manner of selecting which faces to use or exclude is considered by the inventors of the present disclosure to be unique to 3D printing. A 2D tool is used on a GUI (graphic user interface) to select one or multiple related faces or surfaces per selection. Faces are related in the aspect that they are all part of the same model.

The selection of which faces are to be selected is done as follows. A 2D box from the angle of view (from the perspective of for example a camera) is used and a real time check is performed for every face that is in or intersects with this box. This follows the logic that only faces or surfaces are selected nearest to the view / camera and surfaces or faces which are facing towards the camera.

Every (de)selected face may be given a colour to indicate that this face is (de)selected.

Regarding the math of ‘Selection of faces’, the following disclosure is provided:

1) Define 2D Tool boundary box as polygon

2) Nearest intersected triangle:

$$- \text{Face}_{\text{intersected}} = N_{\text{camera}} \neq \text{Direction}_{\text{face}} \ \& \ \text{Distance}_{\text{camera}} \leq \text{Distance}_{\text{face}}$$

3) Find all neighbour triangles from $\text{Face}_{\text{intersected}}$ that has 2D point in 2D Tool boundary box

$$- \text{Faces}_{\text{in2dtool}} = N_{\text{camera}} \neq \text{Direction}_{\text{face}} \ \& \ \text{Distance}_{\text{camera}} \leq \text{Distance}_{\text{face}} \ \&$$

$\text{IsNeighbourFace}_{\text{intersected}}$

4) Update previous selected faces with newly (de)selected faces

5) Mark Faces_{in2dtool} as (de)selected

Auto orientation is an aspect of the present disclosure. The orientation is determined as follows:

After selection of these surfaces or faces, the program assigns a factor to each face (3 point spatial plane) that makes up the surface. This factor determines the weight of the orientation of the face and is calculated by the surface area of the face. Optionally, users may be allowed to input factors, to be taken into account when performing the method.

10 Multiplying the orientation of the face with the factor normalises the face orientation value. Next the average is taken of all the normalized bi-rotational axis of the selected faces in the model, resulting in a single net orientation of the model.

After the auto orientation, it has become possible to provide supports in an automated manner.

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Regarding the math of 'Auto orientation', the following is noted:

1) Calc average selected face normals

- $N_{total} = Faces_{selectedin2dtool} * N_{SelectedFacesin2dtool}$
- $V_{total} = Faces_{selectedin2dtool} * V_{SelectedFacesin2dtool}$
- $N_{avg} = Normalise(N_{total} / V_{total})$

20

2) Calc model rotation angle

- $Angle_Z = Tan(Normal_{selectedFaceY}, Normal_{selectedFaceX})$
- $Matrix_{rotation} = Matrix_Z * -Angle_Z$
- $Vector_{rotation} = Normal_{selectedFace} * Matrix_{rotation}$
- $Angle_Y = Tan(Vector_{rotationZ}, Vector_{rotationX})$

25

3) Rotate model using the $Angle_Z$ and $Angle_Y$

Regarding the math of Limited (user) bi-axial rotation freedom, the following is noted:

30 After the model has been automatically (or manually) orientated there is a bi-directional window in which the model can be manually orientated if required by the user or to minimize the needed supports. This movement is limited to the degree that the chance that any selected surface needs supporting is minimised. The window of freedom is the combined result of predefined material settings and selected faces in the model.

35 This envelope is visualised in the GUI to indicate to the user where the orientation limits are.

Regarding the math of “Lay Flat using auto orientation”, the following is noted:

The user may select one or more surfaces (a collection of faces facing the same direction), the orientation of the model is calculated and the model is laid flat on the virtual build platform using this orientation.

5 Math ‘Lay Flat using auto orientation’:

1) Calc lay flat rotation angles:

$$- \text{Angle}_Z = \text{Tan}(\text{Normal}_{\text{selectedFaceY}}, \text{Normal}_{\text{selectedFaceX}})$$

$$- \text{Matrix}_{\text{rotation}} = \text{Matrix}_Z * - \text{Angle}_Z$$

$$- \text{Vector}_{\text{rotation}} = \text{Normal}_{\text{selectedFace}} * \text{Matrix}_{\text{rotation}}$$

10 $- \text{Angle}_Y = \text{Tan}(\text{Vector}_{\text{rotationZ}}, \text{Vector}_{\text{rotationX}})$

2) Rotate model using the Angle_Z and Angle_Y

Identification of the support locations in the model is performed as follows:

15 In order to calculate the support locations the model is sliced using a predefined layer thickness. Every slice will have features which are converted in to polygons (vectors), each vector has a location.

After slicing and determining the polygons, the current layer is compared to the previous layer when assessing the entire slice stack from bottom to top, the build platform is or carries the first layer.

20 First the model is analysed for “lowest polygon(s)”, a lowest polygon are vectors on a location where in the previous slice (underneath) there was no vector(s)/polygon(s) on that location.

This is an important step.

25 Next the directional overhang of the subsequent layers is determined. This is done by comparing the current layer with the previous layer. The lowest polygon of the feature is taken as the origin. The current layer is then compared to the previous layer. If the area of the feature is larger than the area of the previous layer then there is/are overhang(s), once the overhang reaches a predetermined value a support location is placed.

30 Upon further assessing the model once a support is placed the support value is subtracted from the overhang value which should result in zero or less. If the overhang value is more than zero, one or more support will be placed.

The placement of these supports can only be placed outside of the periphery of the previously placed supports and in layers above the lowest polygon(s) according to predefined patterns.

35 Regarding the math of ‘Identification of the support locations in the model’, the following is noted:

Step 1: Support point(s) using lowest polygon(s)

1) Determine polygons without polygon below

a. $\text{Polygon}_{\text{lowest}} = \neg(\text{PointInPolygon}(\text{Polygon}_{\text{currentlayerindex}}, \text{Polygon}_{\text{previouslayerindex}}))$

2) Determine $\text{SupportPoints}_{\text{polygonlowest}}$ in $\text{Polygon}_{\text{lowest}}$

5 a. (next) polygon offset with 'material overhang value'

i. When polygon offset exists create support cones on $\text{Polygon}_{\text{offset}}$ using 'material support cone distance'

o Goto 2a.

o When polygon offset not exists

10 • Polygon offset with 'material overhang value / 2 + (2 * material support cone top radius)'

o When polygon offset exists create support cones on $\text{Polygon}_{\text{offset}}$ using 'material support cone distance'

o When polygon offset not exists create support cones using $\text{Polygon}_{\text{lowest}}$

3) Polygons above $\text{Polygon}_{\text{lowest}}$ which are connected by 3D face connection

a. $\text{Polygons}_{\text{abovelowestpolygon}} = \text{For}(\text{Polygon}_{\text{lowestlayerindex}} + (1.. \text{'material property max lowest polygons'})) \ \& \ \text{IsConnectedByFaceConnection}$

4) Determine support cone points using 'material property lowest polygon offset values'

20 a. $\text{For}(\text{value in 'material property lowest polygon offset values'}) \ \text{Polygon}_{\text{intersectionlines}}$ from $\text{Polygons}_{\text{abovelowestpolygon}}$

b. When $\text{Polygon}_{\text{intersectionlines}} > 0$

i. Append $\text{SupportPoints}_{\text{polygonlowest}}$ on $\text{Polygon}_{\text{intersectionlines}}$ using 'material support cone distance'

25 Step 2: Support point(s) using polygons (start with buildplatform layer)

1) Determine polygons $\text{Polygon}_{\text{currentlayer}}$ and $\text{Polygon}_{\text{nextlayer}}$

2) Determine current supported layer

30 o $\text{Polygon}_{\text{supportedlayer}} = (\text{SupportPoints}_{\text{polygonlowest}} < \text{currentlayerindex}) * \text{'material property overhang distance'} + (\text{SupportPoints}_{\text{normal}} * \text{'material property overhang distance'})$

3) Subtract $\text{Polygon}_{\text{nextlayer}}$ with $\text{Polygon}_{\text{currentlayer}}$ and $\text{Polygon}_{\text{supported}}$

o $\text{Polygon}_{\text{difference}} = \text{Polygon}_{\text{nextlayer}} - \text{Polygon}_{\text{currentlayer}} - \text{Polygon}_{\text{supported}}$

4) Append $\text{Polygon}_{\text{difference}} \text{SupportPoints}_{\text{normal}}$ to $\text{SupportPoints}_{\text{normal}}$

35 o Determine $\text{Polygon}_{\text{difference}} \text{SupportPoints}_{\text{normal}}$ from $\text{Polygon}_{\text{difference}}$ using above offset algorithm

- 5) Remove points from $\text{SupportPoints}_{\text{normal}}$ that do not exist in $\text{Polygon}_{\text{nextlayer}}$
- 6) Goto 1 for next layer

In general, some unique features of the present disclosure involve:

- 5 All calculations may be made according to real world material properties from an existing material library.

As for further features:

- All calculations may be performed via asynchronous multi threading, significantly reducing processing time. The determination of the lowest points, the calculation of polygons/vectors, overhang determination, counting polygons, determination of faces that are inside the selection box and colouring of the GUI may all be done via multi threading.
- 10

The unique features lead to a new approach and a new way of working to support models for 3D printing.

- The new way of working is to load a model, to select with a paintbrush like tool where not to place any supports and getting visual feedback where these supports are not to be placed, then to press a single button, a model for printing an object may automatically be extended with support elements or posts and placed in the ideal position / orientation and after a user's confirmation, supports may also be automatically placed using the available material library to define the extended model.
- 15

- 20 As for proper model support, the following is noted

Supports need to be placed correctly, otherwise print jobs fail.

Add model

Lay Flat

-> Select 1 or more surfaces

- 25 -> Calculate surface factor dependent on surface volume (insert math)

-> average bi rotational angle by normalising surface angles with surface volumes (insert math).

-> auto rotate to lay flat on selected surface (insert math)

- 30 Auto orientate

Select support-free areas

-> Use 2D tool on GUI to (de)select one or multiple related faces (3 connected spatial points), creates boundaries

-> Check every triangle that intersects the selection box boundaris which are the nearest to the camera, and the triangle normal is facing the camera

- 35 -> change color of selected faces for visual indiation

-> Calculate surface factor dependend on surface volume
 → average bi rotational angle by normalising surface angles with surface volumes (insert math)

-> calculate maximum allowable bi rotational axle angles, defined by material properties

5 -> visualise rotation envelope in GUI

-> Identify support locations

-> Orientate model to minimize supports (insert math)

-> Identify support locations

10 -> Calculate lowest point facing down supports (insert math)

-> calculate remaining supports from lowest points with overhang (material properties) and predefined ofsets (material properties) (insert math)

Model contour difference, model gaat er van uit dat de vorige laag goed ondersteunt is.

-> Divide the model in slices, each slice comprising a number of polygons.

15 -> Check if individual polygons in each slice is carried, referring to underlying layer(s).

-> a polygon without being carried by an underlying layer (relative to a build platform) is overhang or a lowest point.

-> when overhang exceeds a threshold relative to a closest support element, supporting an underlying layer, a further support elements needs is to be added.

20 Specific parameters may be involved, such as distance from a closest support element, obliqueness of the overhang, support element patterns, and the like.

Preferably support elements are placed at a peripheral edge of an object in a slice, and only in object slices above a lowest point of the object (closest to the build plarform of a 3D printer)..

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About the calculations, the following is noted: all calculations may be performed asynchronously through multi threading, such a determining: - lowest polygon(s) (closest to the build platform) and highest polygon(s) (farthest from the build platform) and object contours in slices, - polygons, - overhang, numbers of polygons, - faces falling inside a selection box, - colouring faces in the selection box of faces having received a selection from the user, and the like. However, calculations for determining support element locations are not subject to asynchronous multi-threading calculations.

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Support shape

35 -> the shape of the support cone is automatically calculated by using the resin properties, support height and calculated load on the support.

Based on the following disclosure, below an embodiment description is provided, referring to the appended and non-limiting embodiment drawing, in which the same, similar or other reference signs may be attributed to the same or similar aspects components or functions of the present disclosure, and in which:

Figure 1 show 2D display of a model or a printed object to which the model corresponds;

Figure 2 shows manipulations to be performed by a user on the 2D display of the model of the object to be 3D printed;

Figure 3 shows addition of support elements or posts to arrive at an extended model for printing of the object to be printed with the support elements; and

Figure 4 shows breaking off of the support elements after 3D printing.

Figure 1 shows a 2D display of a model 1 of an object to be 3D printed (or the object resulting from 3D printing itself). The present embodiment description will proceed under the assumption that figure 1 shows what is displayed in the GUI. In the shown embodiment, the model 1 displayed on a 2D display, such as a display screen in a Graphic User Interface (GUI), is highly simplified as a tilted cube to assist proper understanding of the present disclosure.

Figure 2 also shows the model 1 being displayed in a Graphic User Interface (GUI) 2, with tools 3, 5, 6, 7, 8 for manipulation. A user is able to manipulate the displayed view of the model 1 using translation and rotation arrows 3, until a surface or face 4 comes into view (from a type of camera perspective) that the user wants to select. Surrounding a cursor 5 is an optional selection box 6. The model 1 is displayed relative to a reference 7, which may correspond with a build platform of a 3D printer. When surface or face 4 has been brought into frontal view, the user may select surface or face 4 to indicate his/her desire to keep a selected face or surface 4 free from support elements or posts 9 by selection of an appropriate option 8 from the possibilities of adding support elements or posts 9 or avoiding support elements or posts 9 at the selected surface or face 4, for example by clicking with the cursor 5 on the desired surface or face 4, and then also placing box 6 or at least cursor 5 on the surface or face 4 to be selected, and clicking again. The order may be reversed. Thereby, the entire surface or face 4 of the model is recognized as a selected surface or face 4 to be kept free – at least as much as possible – of support elements or posts 9. Based on such a received indication, the surface or face 4 may be oriented correspondingly, relative to reference 7 of – for example – the build platform of a 3D printer. For example, prior to actual printing, the model may be rotated along arrows A to position the surface or face 4 as much as possible away from the reference 7. The disclosure therefore provides automatic re-orienting the model 1 relative to the reference 7, to avoid addition of posts 9 at surface or face 4 (as much as possible). Since the user does not need to know the position of the reference 7 for the system, method and functionality of the present disclosure to be achieved, display of the reference 7 may

be omitted. The only essential input / output is then that the user can indicate which surface or face 4 is to be kept free from support elements as much as possible. The system of the 3D printer, performing the method of the present disclosure will orient the object relative to the reference.

The user may alternatively orient the object relative to the reference 7, for which display thereof may be important, to indicate thereby which surface(s) or face(s) is/are to be kept free of support elements or posts 9 (as much as possible). Therefore, the user may him- or herself change the orientation of the model 1 relative to the reference 7 using the manipulation keys 3, to set the surface or face 4 at a position and orientation relative to the reference 7, as a consequence of which the number of support elements or posts 9 is minimized in the selected surface or face 4. To allow the user to determine the orientation / position of the model or therefore of the object to be printed during printing relative to the build platform, or other reference 7, the reference should be indicated or visualised otherwise in the Graphic User Interface.

When a position and orientation of the model 1 and/or object to be printed relative to the reference 7 is determined, regardless of whether the reference 7 is actually displayed, support elements or posts 9 are added to the model, to provide the 3D printer with an extended model with added posts 9 for 3D printing of a supported object, in the above described manner, as shown in figure 3.

After 3D printing of the supported object, based on the extended model 1 of the object with support elements or posts 9, the posts 9 may be broken off as shown in figure 4. Breaking off the posts 9 often leaves visible marks, which is why the present disclosure enables a purposeful selection by a user of surfaces or faces 4 which are to be kept free, at least as much as possible, of support elements or posts 9, as these more visible surfaces or faces of the object then need a minimum of (or even no) further processing, in particular smoothening.

Based on the above disclosure, the scope of protection is defined in the appended claims, and in particular the independent claims. Therefore, the scope is in no way to be limited to any features from the above strategic approach or embodiments description, if not defined in the appended independent claims, and may even encompass, in particular for some jurisdictions, also obvious alternatives, presently not foreseen to be disclosed.

CONCLUSIES

1. Een werkwijze voor ondersteunen op steunelementen, tijdens het 3D-printen van een 3D-printobject op basis van een 3D-printmodel, omvattende;

- 5 - het verschaffen van het model;
- het tonen van een visuele representatie van het model, waarin facetten van de visuele representatie zijn te selecteren door een gebruiker; en
- het ontvangen van invoer van de gebruiker over een selectie van ten minste één van de facetten van de visuele representatie van het model, met betrekking tot ten minste één van het toevoegen
- 10 van steunelementen en oriëntatie van het te printen object tijdens 3D-printen;
- het genereren van een uitgebreide versie van het model met de steunelementen daaraan toegevoegd, op basis van de ontvangen invoer van de gebruiker, met betrekking tot de ten minste éne van het toevoegen van steunelementen en oriëntatie van het te printen object tijdens het 3D-
- printen; en
- 15 - het 3D-printen van de uitgebreide versie van het model.

2. Werkwijze volgens conclusie 1, verder omvattende:

- het ontvangen van invoer van de gebruiker over beweging, omvattende ten minste één van translatie en rotatie van de visuele representatie van het model, voorafgaand aan het ontvangen van
- 20 de invoer van de gebruiker over de selectie van ten minste één van de facetten van de visuele representatie van het model, rekening houdend met het toevoegen van steunelementen.

3. Werkwijze volgens conclusie 1 of 2, verder omvattende:

- voorafgaand aan 3D-printen, het ontvangen van invoer van de gebruiker over oriëntatie van het
- 25 object, omvattende ten minste één van translatie en rotatie van het object tijdens 3D-printen, en het oriënteren van de uitgebreide versie van het model tijdens 3D-printen, op basis van de ontvangen invoer van de gebruiker over de oriëntatie van het object.

4. Werkwijze volgens conclusie 1 of 2, verder omvattende:

- 30 - het oriënteren van de uitgebreide versie van het model, met daaraan toegevoegd steunelementen voor 3D-printen, op basis van de ontvangen invoer van de gebruiker, rekening houdend met toevoeging van steunelementen.

5. Werkwijze volgens conclusie 4, omvattende het oriënteren van de uitgebreide versie van het model, met steunelementen daaraan toegevoegd voor 3D-printen van het object, ten opzichte

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van een printplatform van een 3D-printer, van welk platform steunelementen zich uitstrekken om het te printen object te ondersteunen.

6. Werkwijze volgens conclusie 4 of 5, omvattende

- 5 - het toeschrijven van gewichtsfactoren aan de facetten op basis van oppervlakken van de facetten;
- het vermenigvuldigen van oriëntaties van de facetten met de overeenkomende gewichtsfactoren;
- het middelen van genormaliseerde bi-rotationele assen van de facetten; en
- het door aanpassen van de oriëntatie, genereren van een geoptimaliseerde oriëntatie van het model voor het printen van het te printen object, welke is geoptimaliseerd in verhouding met de
- 10 gebruikersinvoer, rekening houdend met ten minste de toevoeging van steunelementen.

7. Werkwijze volgens één willekeurige of meer dan één van de voorgaande conclusies 4 – 6, omvattende

- het tonen van de georiënteerde uitgebreide versie van het model aan de gebruiker;
- 15 - het ontvangen van invoer van de gebruiker over beweging, omvattende ten minste één van translatie en rotatie van de georiënteerde uitgebreide versie van het model, binnen limieten voor het voorkomen van ondersteuning op een facet, dat niet is geselecteerd om ondersteund te worden; en
- het aanpassen van de georiënteerde uitgebreide versie van het model, voor het ontvangen van
- 20 invoer van de gebruiker over beweging, omvattende ten minste één van translatie en rotatie van de georiënteerde uitgebreide versie van het model.

8. Werkwijze volgens één willekeurige of meer dan één van de voorgaande conclusies, waarbij het genereren van een uitgebreide versie van het model, met daar steunelementen op

25 aangebracht, omvat:

- het in plakken snijden van het model;
- het converteren van eigenschappen van elke plak in ten minste één van polygonen en vectoren op locaties van de facetten;
- het bepalen van ten minste één punt van het model, dat overeenkomt met een punt van het te
- 30 printen object, dat zich het dichtst bij een 3D-printplatform van een 3D-printer bevindt.

9. Werkwijze volgens conclusie 8, verder omvattende:

- van een plak omvattende het punt van het van het model, dat overeenkomt met een punt van het te printen object, dat zich het dichtst bij een 3D-printplatform van een 3D-printer bevindt,
- 35 het bepalen van directionele uitkraging van opeenvolgende plakken, door het vergelijken van een huidige laag met een voorgaande laag, die zich dicht bij het bouwplatform bevindt, waarbij het

punt van het model, dat overeenkomt met een punt van het te printen object, dat zich het dichtst bij een 3D-printplatform van een 3D-printer bevindt, als de oorsprong wordt genomen; en

- het vergelijken van de huidige laag met de voorgaande laag, en, als het oppervlak daarvan groter is dan het oppervlak van de voorgaande laag, is het bepaald dat er uitkraging is, en wanneer

- 5 uitkraging door opeenvolgende plakken een vooraf bepaalde waarde bereikt, het aanbrengen van het steunelement in de uitgebreide versie van het model.

10. Werkwijze volgens conclusie 9, verder omvattende het slechts buiten de omtrek van de eerder geplaatste steunen, en in plakken boven het ten minste éne punt van het model, dat

- 10 overeenkomt met een punt van het te printen object, dat zich het dichtst bij een 3D-printplatform van een 3D-printer bevindt, aanbrengen van steunelementen volgens een vooraf gedefinieerd patroon van steunelementen.

11. 3D-printer of computer omvattende een processor en een geheugen, waarbij het

- 15 geheugen omvat: een programma dat is geconfigureerd om de 3D-printer in staat te stellen om de stappen van de werkwijze volgens één willekeurige of meer dan één van de voorgaande conclusies uit te voeren.

12. Gegevensdrager, dat een computerprogramma opslaat, dat een 3D-printer of een

- 20 computer in staat stelt om, wanneer het computerprogramma daarin geladen is, de stappen van de werkwijze volgens één willekeurige of meer dan één van de voorgaande conclusies 1 – 10 uit te voeren.

1/2

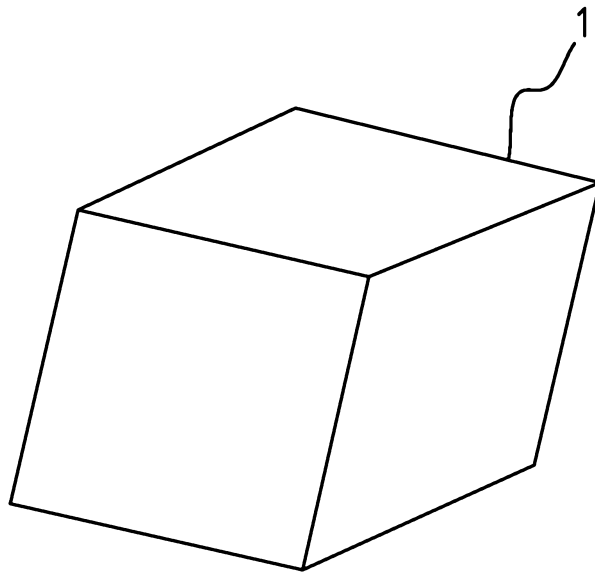


FIG. 1

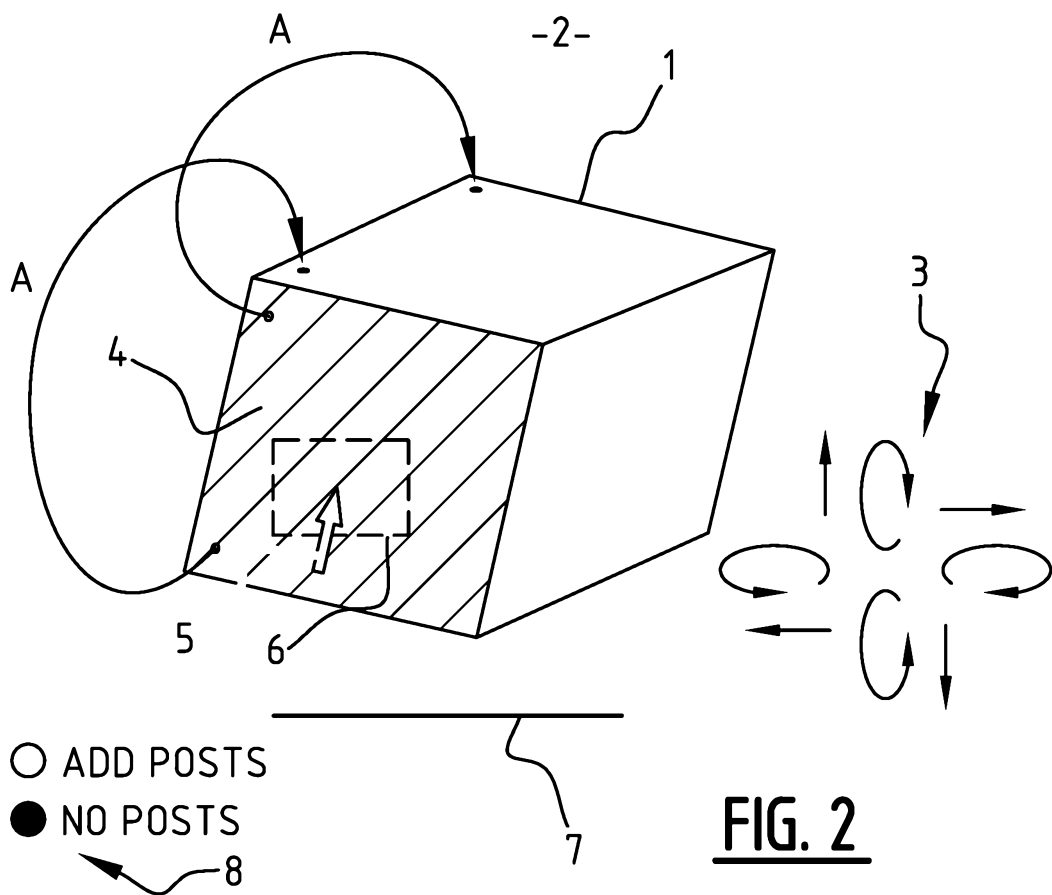
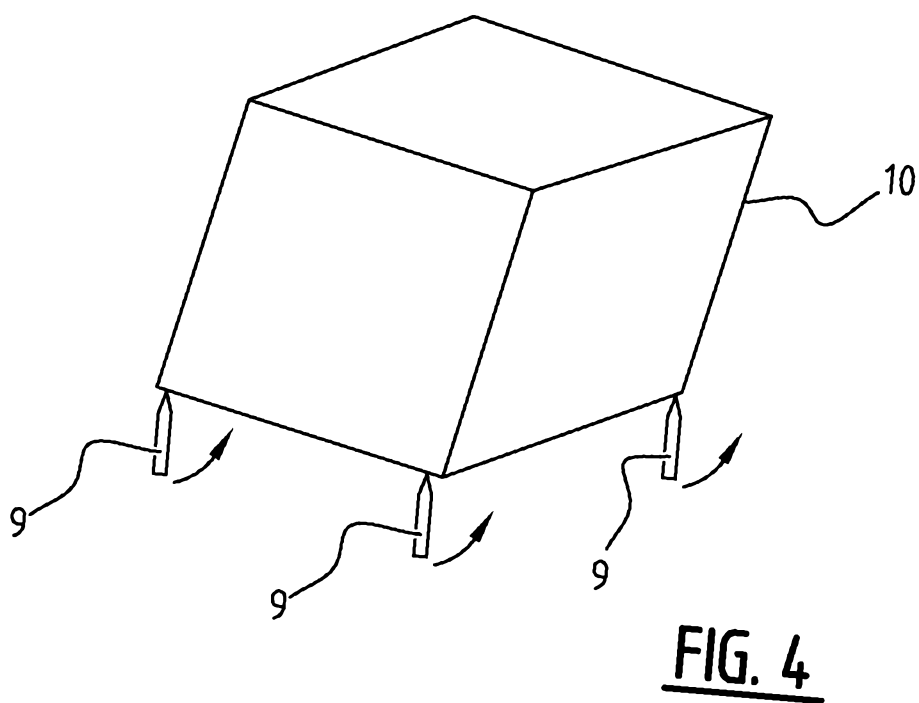
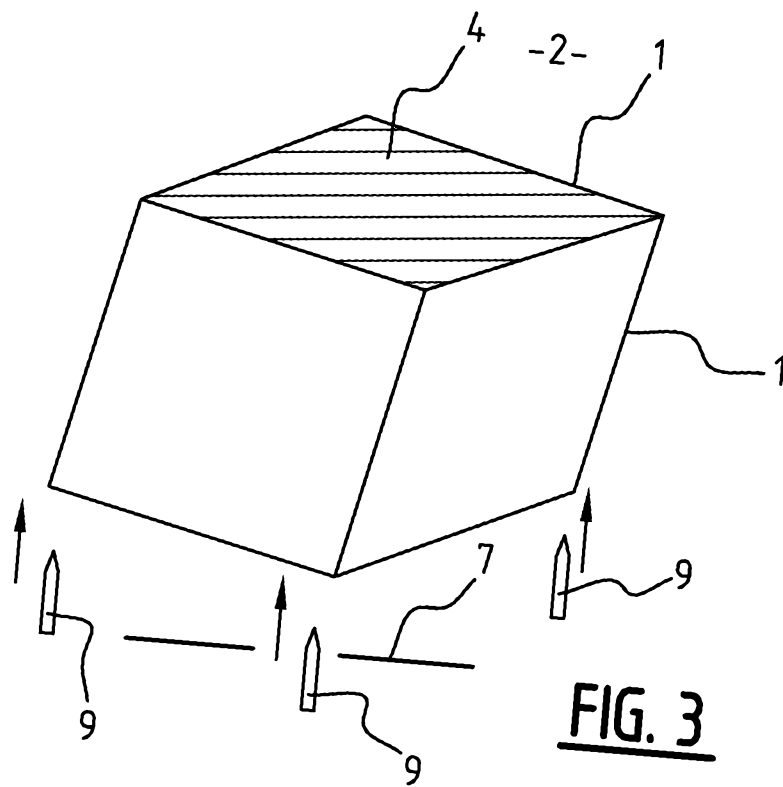


FIG. 2



ABSTRACT

The present disclosure relates to method of supporting on support elements during 3D printing of a 3D print object based on a 3D print model, comprising:

- 5 - providing the model;
- displaying a visual representation of the model in which faces of the visual representation are selectable by a user; and
- receiving input from the user on a selection of at least one of the faces of the visual representation of the model with respect to at least one of addition of support elements and orientation of the
- 10 object to be printed during 3D printing;
- generating an extended version of the model with support elements added thereto, based on the received input from the user with respect to the at least one of addition of support elements and orientation of the object to be printed during 3D printing; and
- 3D printing the extended version of the model.

15

FIGURE FOR PUBLICATION:

Figure 2

SAMENWERKINGSVERDRAG (PCT)

RAPPORT BETREFFENDE NIEUWHEIDSONDERZOEK VAN INTERNATIONAAL TYPE

IDENTIFICATIE VAN DE NATIONALE AANVRAGE	KENMERK VAN DE AANVRAGER OF VAN DE GEMACHTIGDE
	W/2SU27/MLa/2
Nederlands aanvraag nr.	Indieningsdatum
2019907	14-11-2017
	Ingeroepen voorrangsdatum
Aanvrager (Naam)	
Atum Holding B.V.	
Datum van het verzoek voor een onderzoek van internationaal type	Door de instantie voor internationaal Onderzoek aan het verzoek voor een onderzoek van internationaal type toegekend nr.
03-02-2018	SN70581
I. CLASSIFICATIE VAN HET ONDERWERP (bij toepassing van verschillende classificaties, alle classificatiesymbolen opgeven)	
Volgens de internationale classificatie (IPC)	
B29C64/386;B33Y50/00;B29C64/40	
II. ONDERZOCHE GEBIEDEN VAN DE TECHNIEK	
Onderzochte minimumdocumentatie	
Classificatiesysteem	Classificatiesymbolen
IPC	B29C;B33Y
Onderzochte andere documentatie dan de minimum documentatie, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen	
III.	☐ GEEN ONDERZOEK MOGELIJK VOOR BEPAALDE CONCLUSIES (opmerkingen op aanvullingsblad)
IV.	☐ GEBREK AAN EENHEID VAN UITVINDING (opmerkingen op aanvullingsblad)

**ONDERZOEKSRAPPORT BETREFFENDE HET
RESULTAAT VAN HET ONDERZOEK NAAR DE STAND
VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE**

Nummer van het verzoek om een onderzoek naar
de stand van de techniek

NL 2019907

A. CLASSIFICATIE VAN HET ONDERWERP

INV. B29C64/386 B33Y50/00 B29C64/40
ADD.

Volgens de Internationale Classificatie van octrooien (IPC) of zowel volgens de nationale classificatie als volgens de IPC.

B. ONDERZOCHETE GEBIEDEN VAN DE TECHNIEK

Onderzochte minimum documentatie (classificatie gevolgd door classificatiesymbolen)

B29C B33Y

Onderzochte andere documentatie dan de minimum documentatie, voor dergelijke documenten, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen.

Tijdens het onderzoek geraadpleegde elektronische gegevensbestanden (naam van de gegevensbestanden en, waar uitvoerbaar, gebruikte trefwoorden)

EPO-Internal

C. VAN BELANG GEACHTE DOCUMENTEN

Categorie *	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
X	Mold3D Channel: "3D Printing Tips using the Formlabs Preform Layer Viewer", youtube, 23 april 2014 (2014-04-23), bladzijde 1, XP054978544, Gevonden op het Internet: URL: https://www.youtube.com/watch?v=jnzKqrZ5qAY [gevonden op 2018-07-26] * Watch from 5:45 mark * ***** -/--	1-12



Verdere documenten worden vermeld in het vervolg van vak C.



Leden van dezelfde octrooifamilie zijn vermeld in een bijlage

*** Speciale categorieën van aangehaalde documenten**

"A" niet tot de categorie X of Y behorende literatuur die de stand van de techniek beschrijft

"D" in de octrooiaanvraag vermeld

"E" eerdere octrooi(aanvraag), gepubliceerd op of na de indieningsdatum, waarin dezelfde uitvinding wordt beschreven

"L" om andere redenen vermelde literatuur

"O" niet-schriftelijke stand van de techniek

"P" tussen de voorrangsdatum en de indieningsdatum gepubliceerde literatuur

"T" na de indieningsdatum of de voorrangsdatum gepubliceerde literatuur die niet bezwerend is voor de octrooiaanvraag, maar wordt vermeld ter verheldering van de theorie of het principe dat ten grondslag ligt aan de uitvinding

"X" de conclusie wordt als niet nieuw of niet inventief beschouwd ten opzichte van deze literatuur

"Y" de conclusie wordt als niet inventief beschouwd ten opzichte van de combinatie van deze literatuur met andere geciteerde literatuur van dezelfde categorie, waarbij de combinatie voor de vakman voor de hand liggend wordt geacht

"&" lid van dezelfde octrooifamilie of overeenkomstige octrooipublicatie

Datum waarop het onderzoek naar de stand van de techniek van internationaal type werd voltooid

7 augustus 2018

Verzenddatum van het rapport van het onderzoek naar de stand van de techniek van internationaal type

Naam en adres van de instantie

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

De bevoegde ambtenaar

Van Wallene, Allard

**ONDERZOEKSRAPPORT BETREFFENDE HET
RESULTAAT VAN HET ONDERZOEK NAAR DE STAND
VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE**

Nummer van het verzoek om een onderzoek naar
de stand van de techniek

NL 2019907

C.(Vervolg) VAN BELANG GEACHTE DOCUMENTEN

Categorie *	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
A	MeshMixer: "3D Printing Support Generator in meshmixer 2.0", youtube, 20 september 2013 (2013-09-20), bladzijde 1 pp., XP054978543, Gevonden op het Internet: URL:https://www.youtube.com/watch?v=aFTyTV3wweE [gevonden op 2018-07-26]	1-12
A	ROHAN VAIDYA AND SAM ANAND: "Optimum Support Structure Generation for Additive Manufacturing Using Unit Cell Structures and Support Removal Constraint", 44TH PROCEEDINGS OF THE NORTH AMERICAN MANUFACTURING RESEARCH INSTITUTION OF SME, deel 5, nr. 2016, 27 juni 2016 (2016-06-27), - 1 juli 2016 (2016-07-01), bladzijden 1043-1059, XP002783386, DOI: 10.1016/j.promfg.2016.08.072 * samenvatting * *	1-12

WRITTEN OPINION

File No. SN70581	Filing date (day/month/year) 14.11.2017	Priority date (day/month/year)	Application No. NL2019907
International Patent Classification (IPC) INV. B29C64/386 B33Y50/00 B29C64/40			
Applicant Atum Holding B.V.			

This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☒ Box No. VII Certain defects in the application
- ☒ Box No. VIII Certain observations on the application

	Examiner Van Wallene, Allard
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WRITTEN OPINION

Application number

NL2019907

Box No. I Basis of this opinion

1. This opinion has been established on the basis of the latest set of claims filed before the start of the search.
2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the application and necessary to the claimed invention, this opinion has been established on the basis of:
 - a. type of material:
 - ☐ a sequence listing
 - ☐ table(s) related to the sequence listing
 - b. format of material:
 - ☐ on paper
 - ☐ in electronic form
 - c. time of filing/furnishing:
 - ☐ contained in the application as filed.
 - ☐ filed together with the application in electronic form.
 - ☐ furnished subsequently for the purposes of search.
3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
4. Additional comments:

Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty	Yes: Claims	
	No: Claims	1-12
Inventive step	Yes: Claims	
	No: Claims	1-12
Industrial applicability	Yes: Claims	1-12
	No: Claims	

2. Citations and explanations

see separate sheet

WRITTEN OPINION

Application number

NL2019907

Box No. VII Certain defects in the application

see separate sheet

Box No. VIII Certain observations on the application

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

- 1 Reference is made to the following documents:
- 2 D1: Mold3D Channel: "3D Printing Tips using the Formlabs Preform Layer Viewer", youtube, 23 april 2014 (2014-04-23), bladzijde 1, XP054978544, Gevonden op het Internet: URL: <https://www.youtube.com/watch?v=jnzKqrZ5qAY> [gevonden op 2018-07-26]

D3: ROHAN VAIDYA AND SAM ANAND: "Optimum Support Structure Generation for Additive Manufacturing Using Unit Cell Structures and Support Removal Constraint", 44TH PROCEEDINGS OF THE NORTH AMERICAN MANUFACTURING RESEARCH INSTITUTION OF SME, deel 5, nr. 2016, 27 juni 2016 (2016-06-27), - 1 juli 2016 (2016-07-01), bladzijden 1043-1059, DOI: 10.1016/j.promfg.2016.08.072
- 3 The present application does not meet the criteria of patentability, because the subject-matter of claim 1 is not new.

D1 discloses as of time mark 5:45

een werkwijze voor ondersteunen op steunelementen, tijdens het 3D-printen van een 3D-printobject op basis van een 3D-printmodel, omvattende;
- het verschaffen van het model;
- het tonen van een visuele representatie van het model, waarin facetten van de visuele representatie zijn te selecteren door een gebruiker; en
- het ontvangen van invoer van de gebruiker over een selectie van ten minste één van de facetten van de visuele representatie van het model, met betrekking tot ten minste één van het toevoegen van steunelementen en oriëntatie van het te printen object tijdens 3D-printen;
- het genereren van een uitgebreide versie van het model met de steunelementen daaraan toegevoegd, op basis van de ontvangen invoer van de gebruiker, met betrekking tot de ten minste éne van het toevoegen van steunelementen en oriëntatie van het te printen object tijdens het 3D-printen; en
- het 3D-printen van de uitgebreide versie van het model.
- 4 Dependent claims 2-9 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of novelty and/or inventive step, see document D1 as a whole, in particular the rotation / translation of the part, the re-orientation of the part to optimize the support structure, minimizing support points within visual range of the object, viewing

layer by layer (slicing) the object which simulates the manufacture sequence and manual removal of support structures, the relation of each slice to the platform, determining the overhang angles by layer comparison. Further features as defined in the claims are considered to be implicitly disclosed in D1, as the algorithms behind the functionality shown in the video cover the aspects of some of the dependent claims.

- 5 The same arguments apply to the subject matter of claims 11 and 12 as all known 3D printers are under computer/processor control.

Re Item VII

Certain defects in the application

- 6 The features of the claims are not provided with reference signs placed in parentheses.

Re Item VIII

Certain observations on the application

- 7 It would appear that claim 11 comprises all the features of claim 12 and is therefore not appropriately formulated as a claim dependent on the latter.
- 8 The subject matter of claim 6 lacks clarity as the wording "gewichtsfactoren", "facetten", "bi-rotationele assen" en "geoptimaliseerde orientatie" are unclear: "gewichtsfactoren" is unclear, as a weight as such is clear, but a weight factor not (to what does the factor refer and what is the unit?). Furthermore, weight is linked to a volume and density of a build material and it is unclear how it is related to a facet (which is a surface), which is moreover also arbitrarily defined by the user.
- "facet" is unclear because it is defined by the user and it is not defined which parameters are used to define a facet (i.e. location, size, shape)
- "bi-rotationele assen" is unclear, as it is not defined which axes are meant and the rotation(s) not being defined.
- "geoptimaliseerde orientatie" is unclear, as the parameter for optimizing is not defined. The multiple unclarities lead to the extend that no meaningful interpretation of the claim could be performed. However, document D3

discloses in its abstract the calculation of support structures depending on the weight of a part. As such, using the weight of an object to determine the support structure is therefore not inventive.