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DIMENSIONAL ADJUSTMENTS FOR BOOLEAN OPERATIONS

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Dimensional Adjustments for Boolean Operations

Abstract

One of the benefits of the 3MF language is that it allows to encode a single geometry representation when multiple instances of the same object are willed to be printed. However, there are situations in which while most of the model is exactly the same, there may be subtle differences like some labeling or small feature attached to the model, which makes it different. To overcome this situation a Boolean operations extension has been proposed. The Boolean Operations extension allow to operation using 3 basic operations (union, difference and intersection) to compose a final object referencing some base models. While this allows a better reuse of geometries in the file, it can introduce some issues when dimensional adjustments are applied, and more specifically when surface offset are applied to the individual geometries referenced from the Boolean operations. In this invention disclosure we propose a method to adjust the position of the Boolean operations models, so that it does not distort the printed object.

Introduction

When applying surface offsets to Boolean operations model, the relative position of the two or more objects being operated will be altered. Considering cases like the part labeling in which a base object is operated with some smaller object representing the label, the label is expected to be printed just touching the surface of the underlying object. However, when applying the surface offset for dimensional adjustment, the position of the surface of the base object may be altered, causing a potential gap between the base object and the label, or that the label is completely inside the underlying object, making it not visible. In this invention disclosure we propose a method which adjust the position of the object in the Boolean operations to compensate the effect that will cause the offset in the underlying object.

Prior to our method there was no mechanism for adjusting the position to the actual offset being applied to the parts. The only option was to consider the offset in the design space by assuring some sort of overlap to guarantee that after an erosion the label will be still in contact with the underlying object. However, this method was not robust as required in the design stage to design with a "worse" case, which may be not enough for the actual case. Our method does a perfect adjustment for the concrete amounts of offset being applied.

Proposed method

Dimensional accuracy is one of the key value propositions for 3D printers, especially for production applications. Production applications usually requires printing multiple copies of complex objects which contain lattice structures, but which are not exactly the same because each part requires its own model. To allow a better handling of the object by a reduced file size, it has been introduced the usage of Boolean Operations. With that, the underlying lattice object is stored just once and the referenced multiple times from different Boolean operations. In each of the Boolean operations, the underlying object is Boolean operated (either union or difference) with some other model representing the label to generate the printed part. The label is intended to be printed in the surface of the underlying object, so that after the object is printed it gets the labels perfectly fused to it.

However, to have a proper dimensional accuracy it is required to perform a surface offset operation on the underlying object. It may be the case that the label object requires a different amount of surface offset, but in most of the cases it will be that the label object will not require any offset as a protection mechanism for the small feature object.

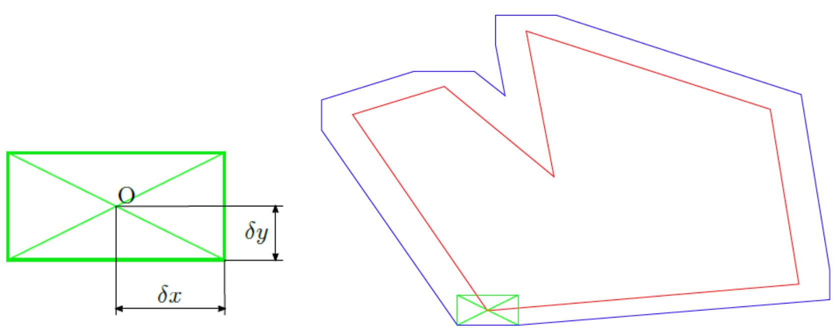
Our method

The proposed method adjusts the position of the Boolean operations object/s (in this case the label object) with respect to the underlying object.

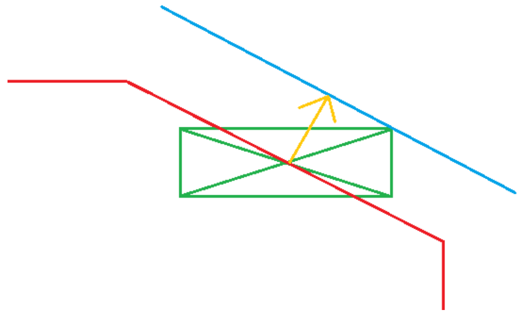
For calculate this translation we are going to apply to the label respect to the main part we need the vector that indicates the direction in which we need to translate it and the value of the translation. The vector is not difficult to calculate, because is the normal direction to the main surface, which can be easily obtained from the normal vectors of the triangles that compose that surface.

The value of the translation, it is, the distance that the label has to be moved from the original surface, is the value of the offset we are going to apply in this part in order to improve its dimensional accuracy. This offset in the orthogonal directions (X, Y and Z axis directions) is easy to know because is directly the value of the offset in that directions. However, in any other orientation is not so easy.

The offset is applied in the printed parts is calculated as the Minkowski sum of the printed part and a brick of the size of the offset in its respective dimensions:

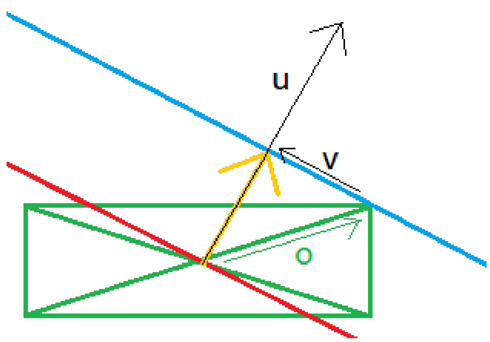


Let see the following scheme:



In it we can see how the red part offseted with the green brick (which has the offset values as dimensions) gives as result the blue surface. And has an *effective offset* represented with the orange arrow in the normal direction respect the main surface.

In order to calculate the value of the modulus of this effective offset, let's notice that it is the projection of the corner of the green brick over the normal vector u, that vector that joins the main surface with the label.



In this scheme, the module of the orange vector may be calculated as

$$|P_{o,u}| = \frac{< o, u >}{|o|}$$

where the vector o is the vector given by (o_x, o_y), it is, the corner of the green brick in the scheme.

In general, the offset vector o that has to be considered for project is that that has the same signs in the X, Y and Z coordinates than the vector u. It is, for example, if vector $u = (2, -1, -3)$, then the vector $o = (o_x, -o_y, -o_z)$.

Thus, the value of the modulus of the effective offset may be expressed as:

$$\frac{< (sign(u_x) \cdot o_x, sign(u_y) \cdot o_y, sign(u_z) \cdot o_z), u >}{\sqrt{{o_x}^2 + {o_y}^2 + {o_z}^2}}$$

Disclosed by Sergio Gonzalez, Victor Diego and Manuel Freire, HP Inc.