Specification and implementation of a parametric operator : Folding

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Abstract: In the early stage of creation, the architect tests his working hypotheses by making many adjustments while designing. During the sketching phase, the existing modeling tools are not compatible with the iterative nature of this process. So the challenge lies in the definition of a model which will allow the whole creative process with its various coming and frowing during the phase of conception. We will illustrate this model by implementing a parametric operator allowing the action of folding. Its parametric specificity will enable the architect, in the design phase, to make the numerous moves alterations required to obtain an optimal shape.

1. INTRODUCTION

The current renewal of formal vocabulary in the world of architecture so-called "non-standard" relies heavily on the use of three-dimensional modellers. In this design, strategy modelling objects falls under the direct use of geometry as the formalization of an idea. Indeed work with such forms requires many adjustments incompatible with a linear geometric modelling. In previous work, we assumed that the genesis of forms result of successive operations processing form and target-based semantic and guided by one or more mental images (Borillo & Goulette, 2002; Estevez, 2001; Rowe, 1987).

This semantic path is a variation between different states of the form and numerous adjustments to the form (Zeisel, 1984).

To formalise this iterative process, we propose a parametric approach based on high level modifier of form. We call morphosemantic operator an action tool that allows finding a satisfactory from a morphological transformation (bulging, twisting, pleating…) by adjustment.

In this article, we propose a specification for one of these morphological operators: the operator “folding”.

2. EXAMPLES OF THE USE OF « FOLDING » OPERATOR

For the buildings[1] that we have previously studied (Wetzel, Belblidia, & Bignon, 2007), we found that parametric operators, and in particular the operator "Folding", can be applied at different scales of the project. They can govern, in a comprehensive manner, the whole volume of a project, or they can be used to shape an element of the project in particular: the roof, walls, etc.

Two recent examples are: the tower in Jeddah Hilal (Hraztan Zeitlian) and an example of chai Spain (RCR Architects).

The Hilal tower, submitted for the contest for the new headquarters in Jeddah of the Islamic Conference Organization, is a crescent moon formed by several folds. The architect used several times the Bend operator applied in a comprehensive manner on the whole building.

[1] The Berlin Jewish Museum by Daniel Libeskind and the Strasbourg Car Park and Terminus by Zaha Hadid.

Figure 1. Hilal Project of Hraztan Zeitlian.

In the draft for a wine and spirits store in Spain, RCR Architects use the kink primarily on the steel roof.

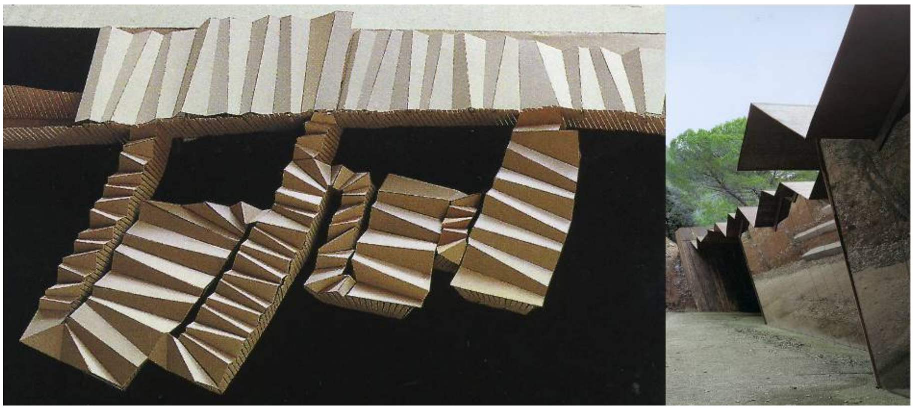

Figure 2. RCR, Example of a winery built in Spain, using on several occasions the operator "folding" for the design of the roof.

3. SPECIFICATION OF « FOLDING » OPERATOR

We found that the three-dimensional modelers that we used (3DS Max, Maya) do not fold the concept of a volume. The user must therefore perform multiple elementary operations to eventually obtain a fold, which, moreover, is not satisfactory since it presents a distortion of the grid on the area of folding, instead of a merger of the two meshes (Figure 3).

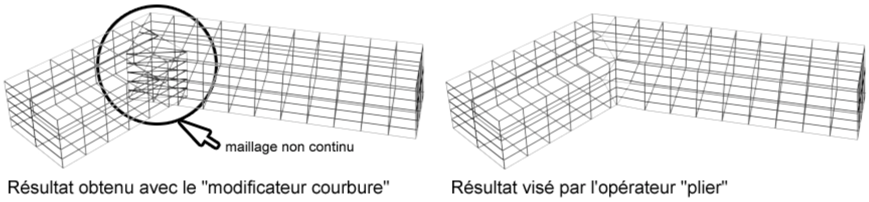

Figure 3. Providing a "folding" operator on the continuity of mesh

We have chosen to define a new operator “Folding” to overcome these two defects.

3.1 General principle

To define the parameters of this operator, we are guided by the process of folding operated by a sheet metal press (figure 4). The object to be bent is placed in a press containing a "Vé" and a "Counter-Vé", the latter turned to bend the metal sheet. We can identify at this stage a bending axis located outside the side of the plate where the angle obtained after bending is inferior to 180°. On the opposite face we see an elongation of the material.

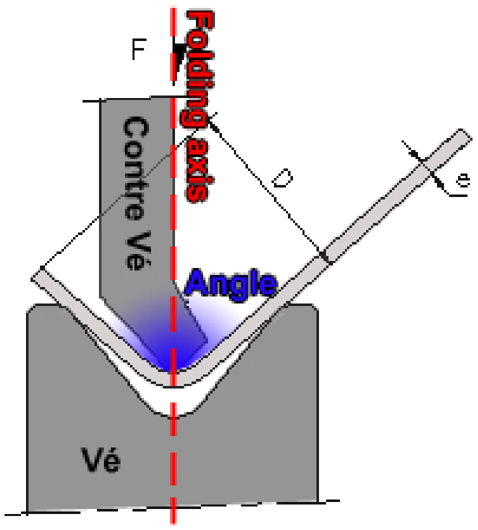

Figure 4. Example of a sheet metal bending machine

On the basis of this system of folding a metal sheet in industry, we generalize the process of folding a volumetric 3D, from two parameters: a “folding” axis and a “folding” angle.

3.2 “Fold” a three-dimensional mesh

As a first step the user defines a folding axis through two points on the surface of the object.

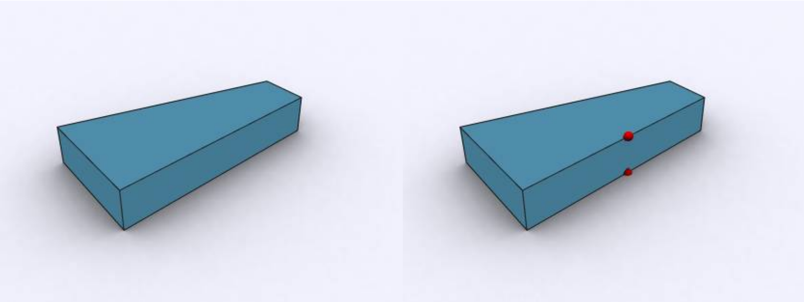

Figure 5. Implementation of the plan folding

From the positioned folding axis, we obtain a fold axis on the outside surface of the geometry to treat, which allows the subdivision of the form into two parts.

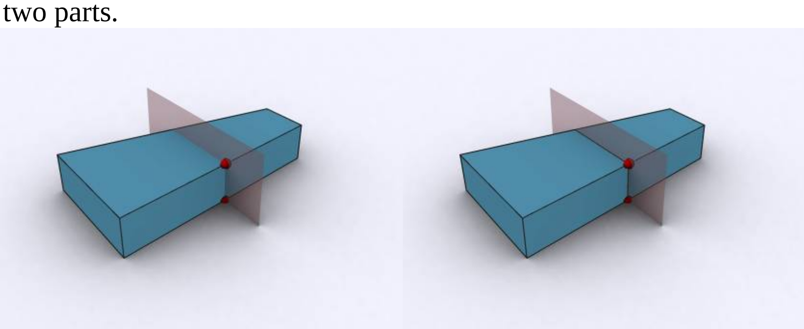

Figure 6. Subdivision of the volume and creating edges intersect at the fold

The folding algorithm performs a rotation of the two previously obtained geometries, following two values around the bend axis. The geometry is then reconstructed by joining the split edges.

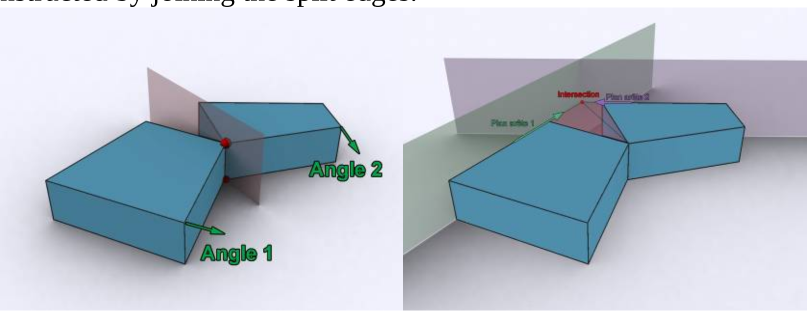

Figure 7. Moving items on the edge of the plan following the folding edges

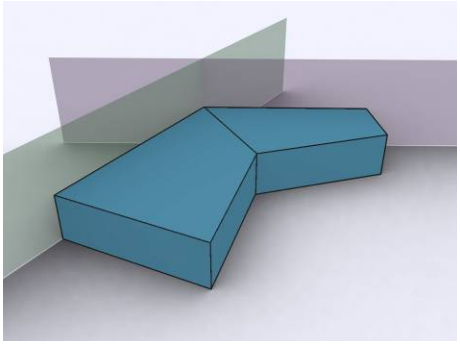

Figure 8. Geometry obtained

The consequence of this process is an overall elongation of the geometry, originating from the folding axis and plan. The integrity of the geometry is globally respected, which is important in the design phase.

We still need to define the use of this operator from the point of view of the interface, in order to obtain a fully functional prototype.

4. USER INTERFACE

We consider it essential to address the aspect of the interface between the user and the operator implemented. We propose to place the settings directly on the geometry (Pranovich, Achten, Vries, & Wijk, 2005) which is to be treated and no longer in a dialog box set beside it.

We could improve ergonomics by using multi-touch screens (Do, 2002) which would add semantic gestures (Figure 9) to the introduction of some operators in the modeling of a project.

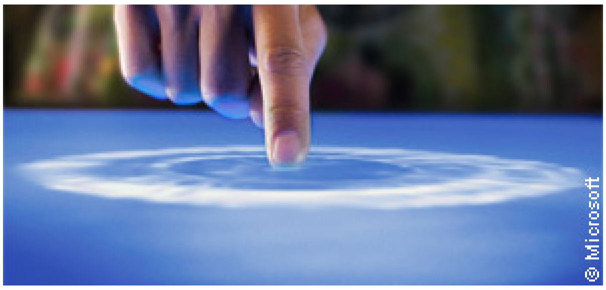

Figure 9. Multi-touch screen "Surface" Microsoft ©

We will develop in the rest of this article the principles for introducing the parameters of the “bending” operator in an environment using a tactile interface.

4.1 The handling of parameters

During the handling of the "folding" operator the user will impact on the change in two types of settings. He will be asked to move the location of the fold and to quantify the value of angular folds.

4.1.1 Variation of the implantation

At the end of the previous section, the fold is located on the geometry to fold axis bending. We propose that the user intervention on this theme is by moving to the geometry of two crucial points that pivot. We represent thias by two red spheres (Figure 10).

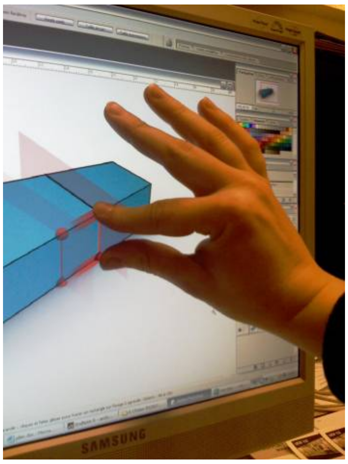

Figure 10. Moving the bending axis by two points.

4.1.2 Angular variation

By touching the geometry, the user operates on the corner of the fold of general geometry, and is thus able to vary at will in order to achieve the optimal shape. (Figure 11)

There are two angular values on which it can operate. Indeed after analysis, it would be preferable to intervene separately on the values of the angles to the left and right of the folding plan because the user may choose to keep a part of the fixed geometry and another moving part.

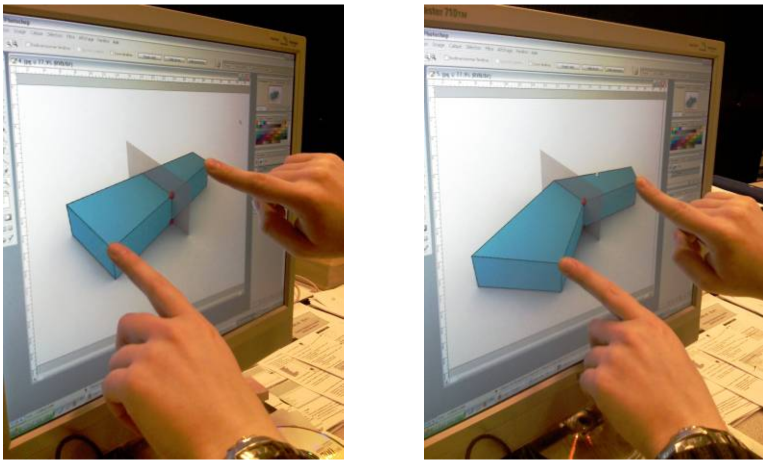

Figure 11. Determination of the overall angle using two angles.

4.2 The insertion of the operator

To apply the operator "folding", the user must define the geo-location of the fold on the geometry. The GSE is determined by an initiator bending axis of the fold.

Taking origami as a basis, we deduce that there are three principles for the definition of this axis:

A Direct definition, which is defined by the user following two points on a ridge outside the geometry, one can directly define the axis of folding. (Figure 12.)

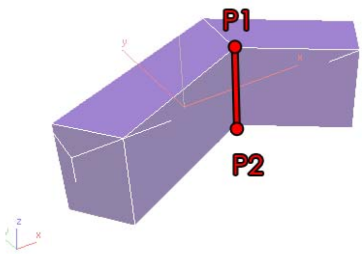

Figure 12. Definition of the axis controls two points of impact.

An indirect definition which leads the user to deduce the location of the fold according to the geometry of the object being modelled. It can be implanted:

- Either through two axes defined by four points.

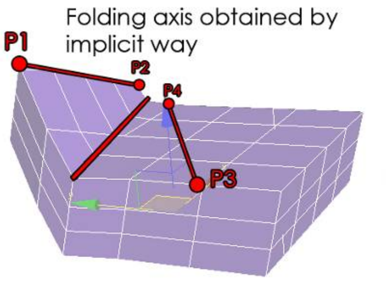

Figure 13. Definition of the axis of control by two points.

- Either through two impact points on the geometry.

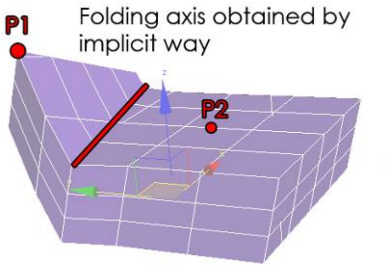

Figure 14. Definition of the axis control two points of impact.

When the fold is geo-localized on the geometry, the user will be able to vary the parameters that we have set out above.

5. VALIDATION OF THE OPERATOR "FOLDING" MODELING OF AN ARCHITECTURAL OBJECT

To validate the implementation of our prototype we model the roof of Cornell University designed by Morphosis (Figure 15) from 9 folds located on a rectangular parallelepiped.

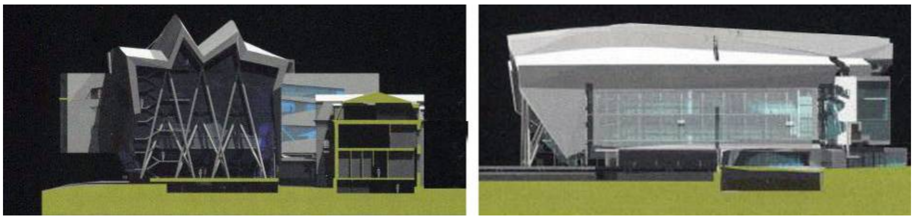

Figure 15. Cornell University by Morphosis.

We chose to use this standard primitive because it allows symbolize a steel plaque of such designer could imagine.

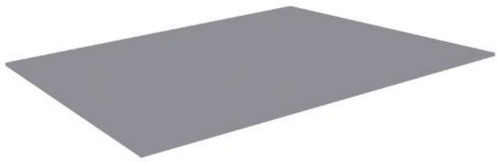

Figure 16. Initial state

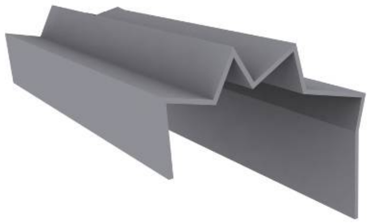

Figure 17. Implantation of the 8 first folds

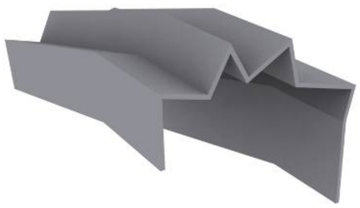

Figure 18. Implantation of the lateral fold

When folding operator is geolocalized on geometry, the user will be able to change the parameters that we have set out above.

6. CONCLUSION

In this article, we have attempted to define and validate a method of implementation and use of the "folding" operator.

The experimental prototype that we implemented has allowed us to test the operator "fold" on various geometries. We have also verified that our interpretation of the action of folding corresponds to a design approach, which is, in essence, iterative and must allow setbacks and adjustments.

As such operators are easy to identify in the modeling process, and since they are adjustable and can thus develop varied spatial solutions, their use in the process of morphogenesis appears more suited to the practice of architecture than the conventional polygonal modeling. The purpose of this approach is to allow the designer to preserve, under the form of a tree, the different stages of morphological transformations, in order to allow him to go back to previous stages to undertake a more detailed formal research.

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