Specification and implementation of a folding parametric operator to Assist Architectural Conception at the Drafting Stage

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Abstract
In the early stage of creation, the architect tests his work 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 trying and going back 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 and returns required to obtain an optimal shape.

Keywords--- fold operator, design aid, modifier, modelisation/modelling.

1. Introduction
More and more architects exploit the possibilities of three-dimensional modellers to create new forms. The strategy of this approach is clearly to formalise an idea.
In earlier work [1], we have assumed that the genesis of these forms results from successive operations of processing forms. These operations have semantic targets and are guided by one or more mental image(s) [2, 3, 4].
But work on these forms, in particular in view of achieving them, often requires many adjustments, which are not compatible with a linear approach of geometric modeling.
This journey consists in many trips back and forth [5] and significant variations between different stages of the form. These characteristics make it an iterative and parametric process.

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

2. « Folding » operator in architecture and design
« The role of the fold is variable: it plays either as a chain result, one inducing an other, either by mutual interaction or quasi-independence. » [6] The fold has several functions, it can be a space or only a structural device. Depending on the scale and the material used, the fold will have a very different characteristic and function.
Folds introduce motion in a form. Its repeated use paves the way for a complex form which is part of the current production. The architect or designer introduces this notion to formalize and materialize an idea. The metaphor of the enlightens used by Daniel Libeskind for the realization of the Jewish Museum in Berlin is the most charismatic example.
Through the buildings¹ that we have previously studied [7], 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 operator Bend 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.
In the draft for a wine and spirits store in Spain, RCR Architects use the kink primarily on the steel roof, as an attempt to reinterpret the traditional roofs Corten steel.

“Folding” operators are also present in design. We can cite the example of Gerrit Rietveld who in 1932 designed the Zig-Zag Chair from a representation of 3 folds. The representation of the kink is thus in conflict with the wood material that, in essence, is not pliable.

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 4.)

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

It must be specified here that a metal sheet, taking account of its proportions, amounts to a plan and that the folding axis is in the plan. How to generalize this process to a volume and thus how to treat surfaces not containing the bending axis.

As a first step the user defines a folding axis through two points on the surface of the object.
From the positioned folding axis, we get a fold axis on the outside surface of the geometry to treat, which allows the subdivision of the geometry into two parts.

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.

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 [8] which is to be treated and no longer in a dialog box set beside it.

We could improve ergonomics by using multi-touch screens [9] which would add semantic gestures (Figure 10) to the introduction of some operators in the modeling of a project.
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.

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, he can directly define the axis of folding. (Figure 11.)

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

- Either through two axes defined by four points.
- Either through two impact points on the geometry.

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

6. Validation of the operator “folding” modelling of the Rietveld chair

In order to validate the specification, we implement this operator in 3D Studio max. We test our prototype with the modeling of Rietveld’s "Zig-Zag Chair" (Figure 3) from 3 folds located on a rectangular parallelepiped. We chose to use this primitive original as a standard because it allows to symbolize a wooden plaque as the designer could have imagined it.
The “Folding” operator has allowed us to model the chair correctly. Moreover, its parametric nature allows the designer to adjust the fold in real time and to go backwards if necessary.

Conclusions

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 architects 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 make him able to go back to previous stages for a more detailed formal research.

References