Applied Generative Procedures in Furniture Design

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Abstract

This paper discusses an approach which combines different generative procedures with design methods as they are common in daily design practice: Two generative tools together with paper models, prototypes and „classical“ Computer Aided Design span the design process. The subject of experimentation is a specific class of furniture: CNC - manufactured, foldable objects for different seating positions, based on a material composition of thin plywood laminated with fabric and / or felt.

The generative tools described below have been developed with the macro programming facilities of the CAD-software I-DEAS. One tool can be used either for systematic exploration of the search space or as a source for inspiration, depending on the preference settings chosen by the user. The other tool is made for the elaboration of details of the generated designs and for preparing production. The prototypes of these tools are still in an experimental stage and just in use to be tested and evaluated. Therefore the charcacter of the following text is more descriptive than analysing.

1. Occasions

About two years ago, while working on my Master Degree Thesis about Genetic Algorithms in Design, I was looking for a suitable example for developing a small generative program to illustrate some of my hypothesises. At the same time Timm Herok, a friend of mine and student of Product-Design, started to develop a composite material based on fabric laminated on thin plywood sheets for Computer Numeric Controlled (CNC) production. The wooden part of the material is milled (mainly) with a 90 degree conic mill tool from one side leaving the fabric untouched. After the milling process the flat sheet can be folded and results in various three dimensional objects according to the milled pattern (see Fig. 1).

In a first short joint design project it was decided to limit the enormous space of possibilities given by this principle towards one very specific class of furniture. We only used milling patterns which are based on two bilateral symmetric splines – to create the basic form – and some straight lines as additional elements and one possibility to fix and to stabilize the folded 3D-objects. Despite this limitation of allowed patterns, the principle still was able to generate a variety of many different kinds of furniture but all speaking the same aesthetic language. The designs of two experimental prototypes, (see Fig. 2) which caused some attention on design exhibitions [1][2], have been realized with help of a generative program, which is the pre-decessor of the program presented in this paper.

The „c-labor“ of the University of Design Offenbach (Germany) [3] is running a research project concerned about the development of (also foldable) designs for mass customization [4] above the somehow boring level of choosing different colours or sizes. That this generative program will be presented on the exhibition of this research project indicates into one field where generative procedures are helpful and may become familiar: Integrating them into a design process to meet the needs and wishes of single customers and – at the same time – having enough performance to link many different individual design to Computer Numeric Controlled manufacturing facilities.

Fig. 1 (left): Stool Protoype – unfolded and folded (Timm Herok) –
Fig. 2: Two Prototypes on exhibitions in Cologne and Kassel (Markus Schein)

2. Tool One – Systematic Exploration and Some Surprises

The developed generative tool is divided into two program parts. The first and main part is made to discover potential types of furniture within the search space of the above mentioned type of pattern. The basic idea was that one shall either have the possibility to explore the search space systematically by reducing the random elements within the generative process or to use randomness to generate more or less unexpected events as a sort of inspiration for the design of new products. The restriction of using only one type of pattern provides one big advantage: There are only some few variables to be maintained within the program and therefore the question about how to organize the complexity of managing a growing number of variables to control the generative process could have been neglected.

2.1 Geometrical Representations, Stucture and Function

2.1.1 Basic Geometric and Design Variables

According to the simplicity of their construction two dimensional patterns – later used as guidelines for the milling process – are sufficient as geometrical representation of the objects. Therefore the main parameters of the objects genetic code are the coordinate pairs of the through points of the splines and the number of these points. The values of the x- and y-coordinates are always chosen by random, the number of these points can be userdefined or also be defined by random (within a range of 3 to 30 per spline). The symetric spline pair basically determines the shape of the later object and therefore also its potential use (as stool, chair, easy chair, chaiselongue, for one, two, more persons...)(see fig. 3).

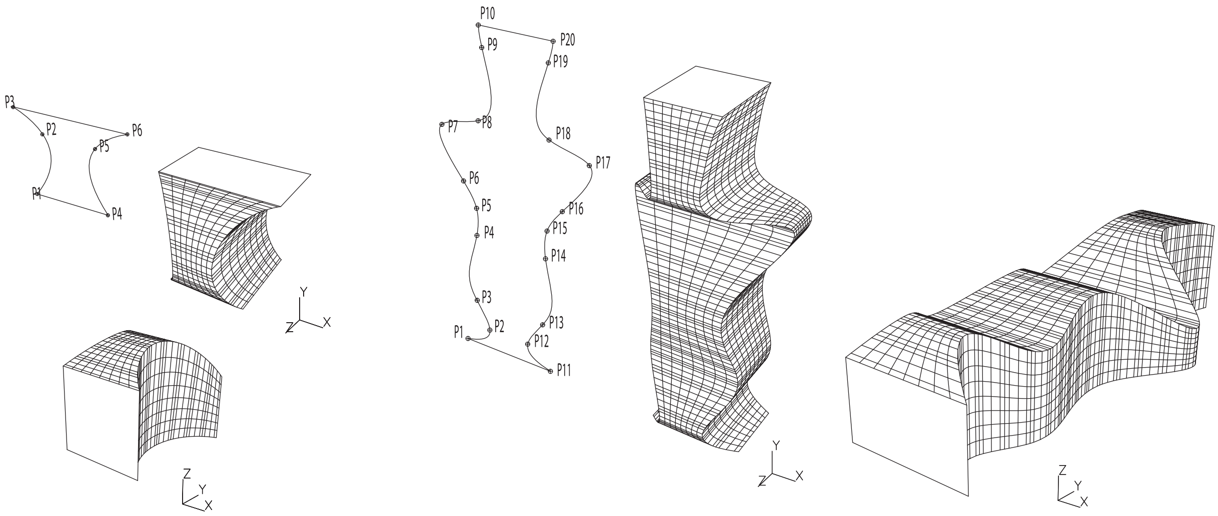

Fig. 3 (left): Two generated objects – the left one maybe could a stool, the right one an easy chair.

2.1.2 Control Variables – Sheet Measures

For a further influence on the generative process, the user can set the board size he then wishes to use for production. In x-direction (perpendicular to the main spline indication) the according variable is equivalent to the exact measure of the sheet. The variable storing the value for the y-direction represents only vaguely the according measure. The actual value depends on the type of folding technique used to close and to stabilize the form (see fig. 4). Mostly this is to be decided at a later stage of the design process.

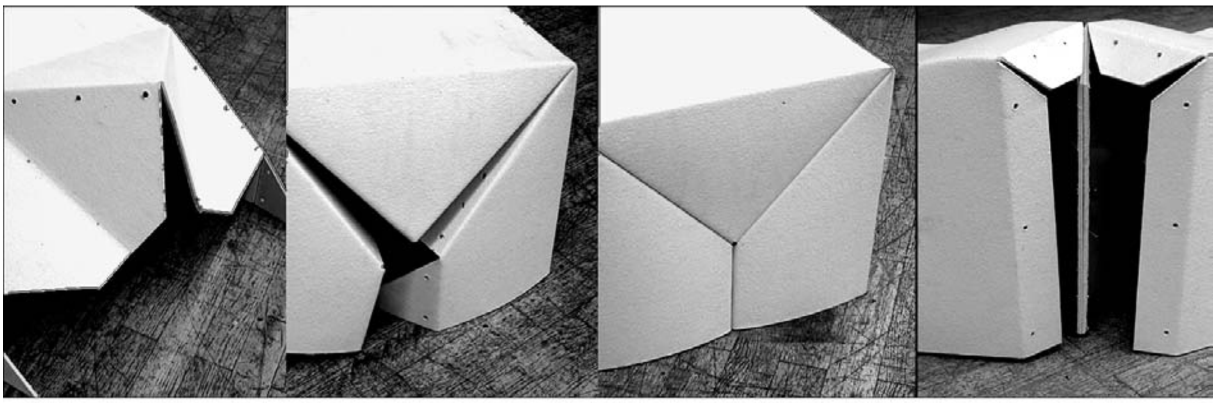

Fig. 4: Two possibilities of closing a form: at the end (three pictures left) and in the middle for building a row of objects.

2.1.3 Control Variables – Spline Generation

To keep the number of variables for user interaction low, there isn‘t provided any influence on the control points of the splines (NURBS) – the standard preferences of the CAD-Software are used. This has the disadvantage that the splines may get very extreme shapes – with an unfortunate random distribution of the co-ordinates of the through points. Sometimes too extreme to generate useful objects. Therefore the program offers four control variables to compensate these effects.

With one variable, the user can determine a minimal distance between the outer border of the sheet (in x-direction) and the nearest through point. This is equivalent to an approximate minimal height of the generated object. He can also define the minimal distance between the spline pair, a rough equivalent of the smallest width available for seating (see fig. 5).

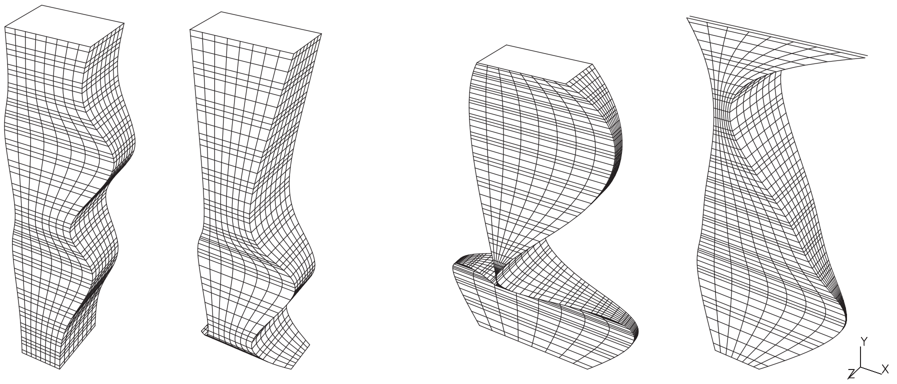

Fig. 5: Four Objects generated with the same settings but the first two ones require a certain minimum height and width, the others do not.

Finally there is the possibility to require a minimal distance between subsequent through points. In y-direction this helps to minimize the risk of self intersecting splines, in x-direction it guarantees that splines have always at least some curvature.

These control variables are all depending on each other – for internal constraint handling the sheet measures are set as dominant, in case of conflicts the other values are adopted accordingly. They do not allow to control the generation of the designs exactly, but – at least – they offer the possibility to take some influence on the basic constraints. This may seem to be unsatisfying but compared with common design processes we are still on the level of sketching, of approaching some idea. Within this stage we usually do not care too much about precision in order to keep the flow of ideas. Due to the precision of computer representations, the generated objects tend to seem much more advanced than they actually are.

2.1.4 Control Variables – Symmetry Operations

Besides the rough control of basic constraints, symmetries have most influence on the potential use of the generated objects and of course on their aesthetic quality. The use of symmetries refers to the whole spline (or some segments of it) along its main indication (in y direction – along the object).

The options are to prohibit the use of any symmetry operation, to use only bilateral symmetry, only translational symmetry or to use both in combination. These settings can be defined by the user or again be left to random choice.

Some Examples: Preference Settings which exclude the use of symmetry, which have about 6 through points per spline and a sheet size which has a bigger length than width, cause objects which indicate to an use as an easy chair for to lie on for one person (see fig. 6).

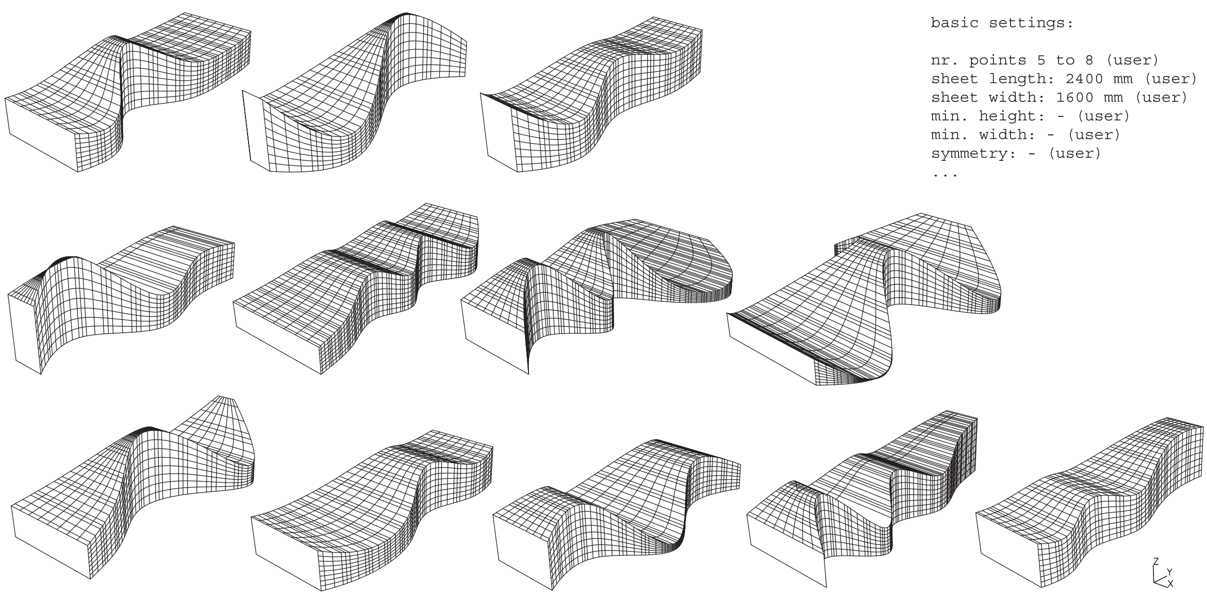

Fig. 6: Twelve more or less promising models for easy chairs ...

Similar settings with a different sheet size (width bigger than the length) and some more control about minimum width and height cause objects which may be developed toward easy chairs for seating (see fig. 7).

Objects for two people – sitting or lying face to face or back to back – are the result of setting which uses one time bilateral symmetry along the splines (see fig. 8).

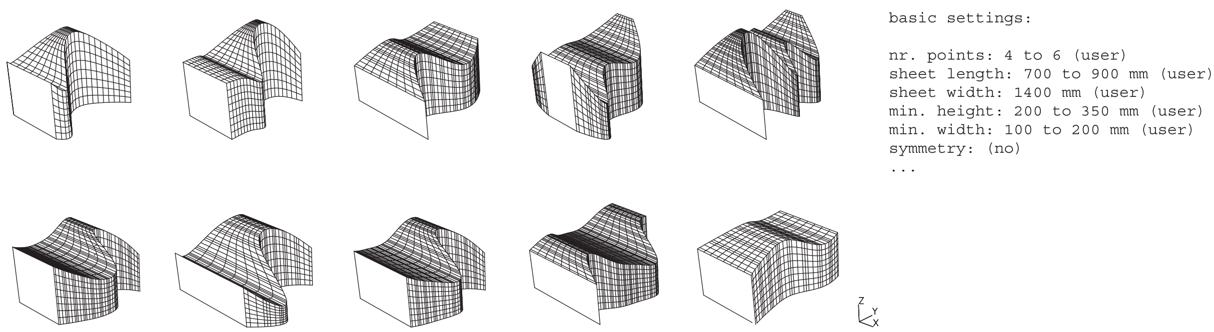

Fig. 7: … and some more potential easy chairs, this time more for seating positions.

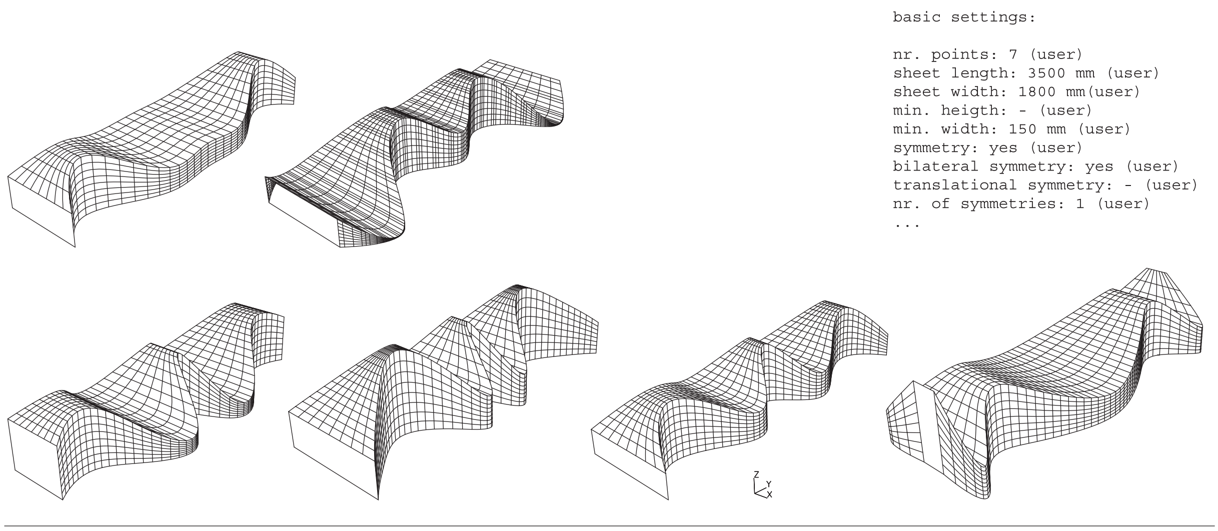

Fig. 8: For two person.

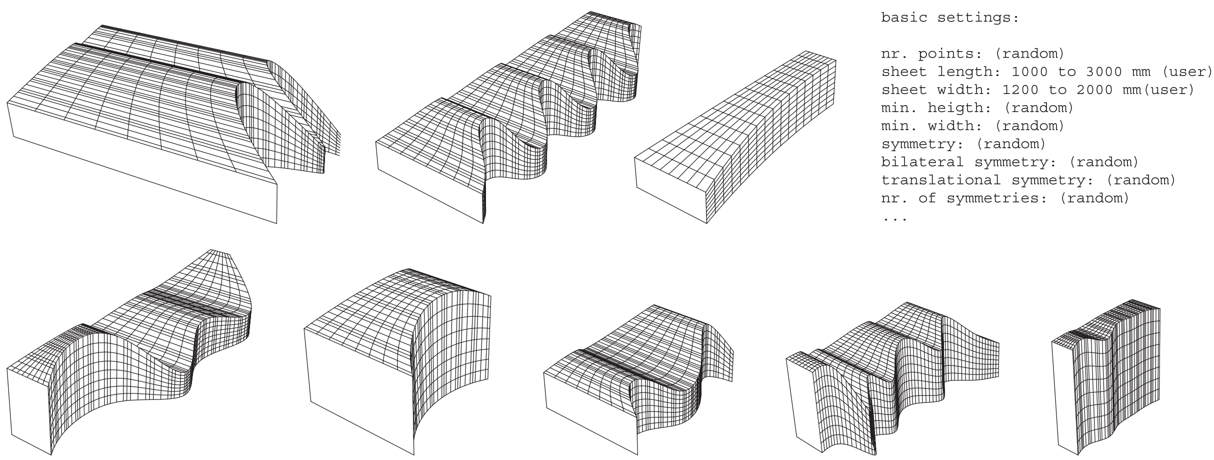

Fig. 9: Models generated with basically random preferences.

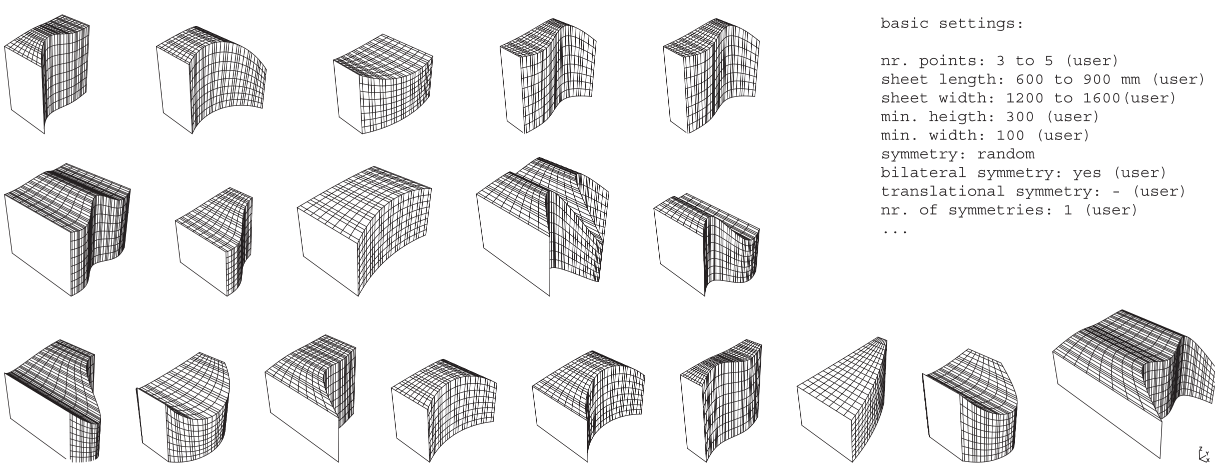

Fig. 10: Stool variations generated with basically userdefined preferences.

Other settings may result in other types of objects, for a lot of them the use still needs to be found or invented. The more of the preference settings are left to random choice, the more objects of this type are generated, offering the opportunity (with some luck and patience) to find some new potential furniture (see fig. 9). The tighter the settings are, the more of them are restricted by the user, the more the generative process tends towards systematic exploration of one type of object (see fig. 10).

The base of the generation of the 3D-objects are reference points homogeneously distributed along the splines of the 2D-pattern. The user can decide whether he wants to represent the objects with the same number of points (see fig. 11) as through points used for the generation of the splines. He can also decide to use less or more points. The use of less reference points simplifies complicated forms, the use of more points allow to work in more details of (especially) simple forms.

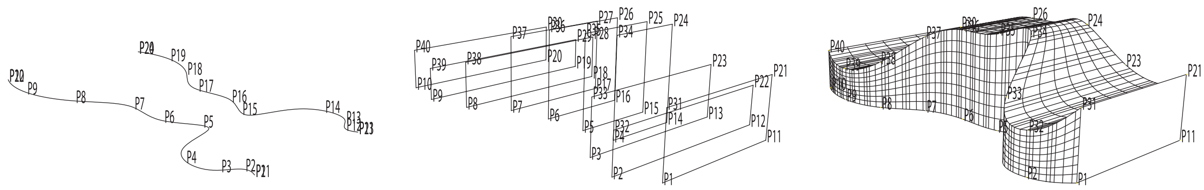

Fig. 11: Model generated with an equal number of through points and reference points.

3. Tool Two – Elaboration of Details – Modelling – Production

In this tool it goes the other way round: now the three dimensional data are used to elaborate the generated designs, the 2D-pattern is only generated if necessary for output purposes.

3.1. Shaping Generated Forms

The coordinates of the wireframes of the 3D-forms are all stored in a library. In this tool, these data are the input to exactly repeat the construction of the chosen object. Then the user can manually change the genetic code, now consisting in triples of coordinates. After having finished the modifications, the object is going to be constructed again, now using the modified genetic code. This way the form can be shaped, worked out in more details. There is the choice to have the symmetrical properties inherited in the objects maintained or rejected. Every time an output for modelling or protoyping is required, the 3D- dimensional object is transferred to the according two dimensional pattern.

3.2 Output for Paper Models (Scale 1:10)

First experiences with this kind of modelling have shown, that it is hard to judge the quality of the objects on the computer screen – on one hand because of the enormous amount of generated objects and on the other hand because of their similarities. It has shown, that paper models in the scale of 1:10 (with uncoated paper of about 120-160g/m^2) are simulating surprisingly good the material behaviour of the real object when being folded. (see fig. 12). If it is hard to fold the 1:10 models and if it starts to crumble it doesn‘t make any sense to go into 1:1 protoypes. There will be too much tension in the material and there is a high risk that it will be damaged. The paper models also can be used to catch a first impression of the anthropometric qualities of the objects: two rough paper models, representing 50 Percentile male and female, are the first probands to test the objects confortability. (see fig. 12).

Fig. 12: First tests about anthropometric quality and material behaviour.

The data output for producing the paper models is simple: A 1:10 snapshot of the two dimensional pattern is automatically taken, transferred into an Encapsulated Postscript File (EPS) and printed to be folded.

3.3 Output for Protoyping (Scale 1:1)

The same procedure is used to generate the data for prototyping. Because EPS-files are also able to store vector data, they can be used as Input for the CAM (Computer Aided Manufacturing) software which is manoeuvring the milling process. However, recent experiences have shown, that this procedure works in general, but causes some problems especially with a certain kind of CAM-software in combination with 5-axis-milling centers, so that this output method probably has to be changed.

For protoyping, two different kinds of milling patterns are generated: The first pattern for formatting the plywood-fabric sheet and to mill the holes for keeping the form together and the second is to mill the folding lines. Up to now, the milling path for the holes has to be added by using the CAD-System in a conventional way: The required paths are placed in generated pattern manually, because the distribution of these holes is not only a static but also a aesthetic question, a question of what kind of technique shall be used: belts, tubes, visible, not visible ... .The same goes with the folding pattern used to close or connect objects.

At the moment, the patterns shown in figure 4 can be automatically generated. If an other pattern shall be used, this also has to be implemented manually with the CAD-System.

4. Summary

For the development of a generative tool to be used beyond the scope of research, these foldable objects have been a lucky case. In the family of furniture they are a extraordinarily closed system with a rather low complexity, maybe comparable with Bentleys tables [5] or Dawkins „Blind Watchmaker" [6]. Even if these two examples use different methods for generating variety (and for selection) than the presented tool, the generated objects are also clearly identifiable as belonging to one very specific kind.

In the real design world, such cases are rare exceptions. Usually we don't know in advance, what kind of materials, forms, fittings, connecting pieces, etc. we will go to use. But more uncertainess about these things also requires more freedom in form generation which – at the end – means more variables to influence, more complexity, more relations between more parts, more complicity which will make the design of a generative software for a broader, multi- purpose use to a task comparable with the development of huge CAD-Systems like Unigraphics, I-Deas or Catia – where lately the philosophy of the company selling the software decides about their – and therefore our – limitations in work [7]. But an other way also seems to be possible: Design education institutions recognise the chance which may be embeded in Generative Design and teach their students other modelling and description techniques such as formatting and programming languages in addition to the usual sketching, drawing and modelling. This would enable people to invent their own generative programs fulfilling their specific requirements.

Wherever the development may go to, still on the prototype level, the first challenges for the described „Foldable Furniture Generator" towards an extension of its possibilities already appear, especially for generating other types of patterns creating completely different kinds of furniture. How big the temptation may be, for this time it is decided: a small extension towards objects, which can be folded in for directions. Then the search for a furniture manufacturer, daring and confident enough, to give the „Foldable Furniture Generator" and its objects a chance in the real design world.

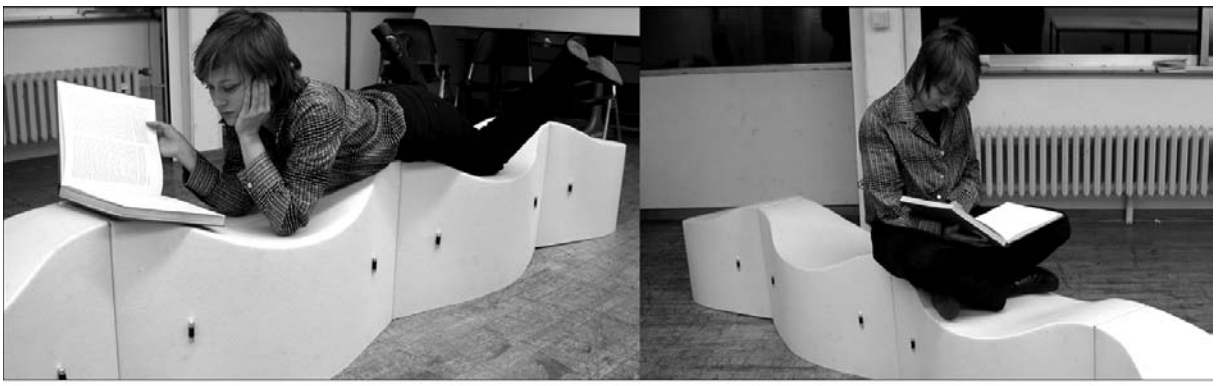

Fig. 13: „Feltworm" – Generated and realized prototype

5. References

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