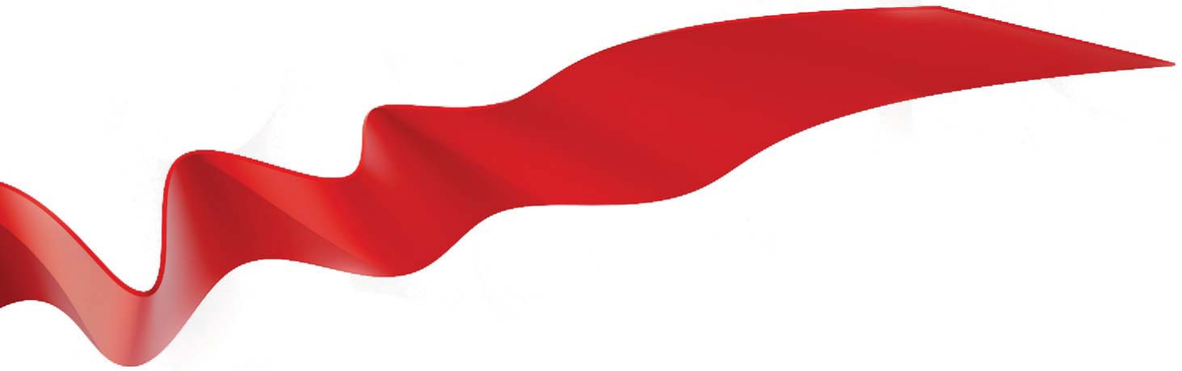
Developables

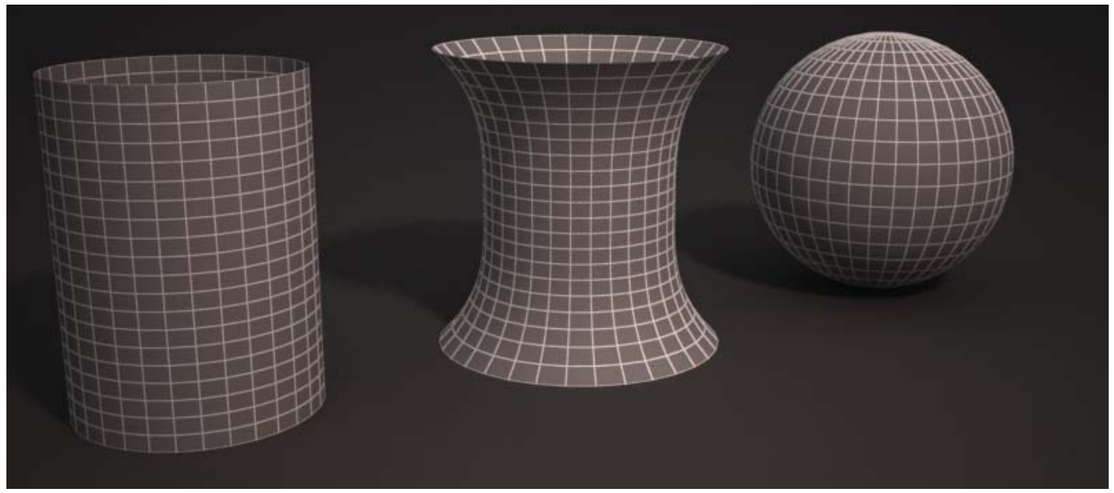
Developable FreeForm Envelopes



Danny te Kloese

What are they?

Developable surfaces are **ruled surfaces**, which means that at every point of itself there exists a straight line which remains within the surface. However not all ruled surface are developable. These surfaces have a 0 gaussian curvature and can so be mapped on a flat surface (unrollable). In simple words, it is **a single curved surface**.

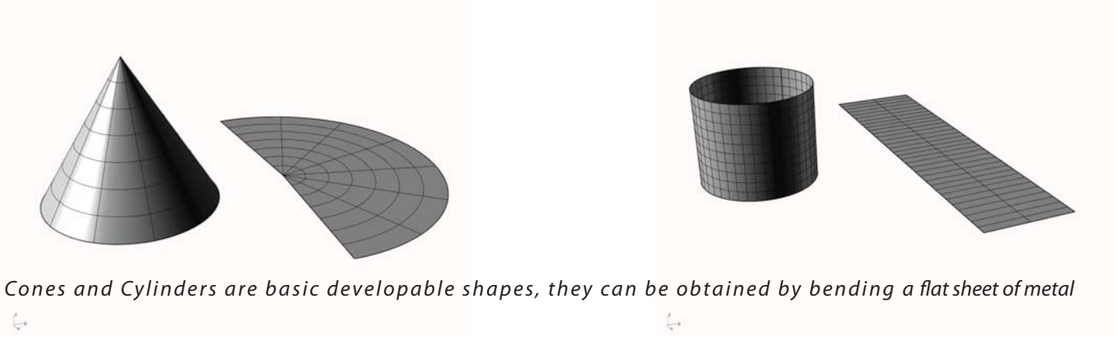


Gaussian Curvature, zero (developable), negative and positive curvature

So what?

In short, it allows architects to use freeform curved envelopes for their buildings **without having to suffer** the negative facts of double curved surfaces. The problem with double curved surfaces is that you're restricted within the choice of materials and you have to resort to expensive technologies in order to *"stretch"* the material.
Single curved surfaces can be easily be obtained by folding a **flat sheet** of material thanks to an (inexpensive & fast) sheet bender.

Sheet Bender in action



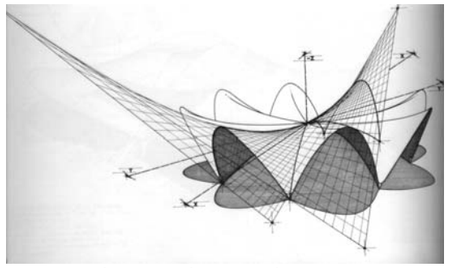
Cones and Cylinders are basic developable shapes, they can be obtained by bending a flat sheet of metal

Is it ncew?

No, not really. The benefic properties of developable surfaces have been known for a longtime in many areas of enginieering. Especially in the domain of aeroplane industry it has proven it's usefullness. In the architecture we began to use this kind of surfaces since the 50's thanks to the constant innovations in concrete. However the forms used within the buildings remained simple because the technologies at that time didn't permit to design more complex forms.
It's only since the last decade of the the past century that the complexity of the projects could evolve thanks to development of computer graphics.

Cristo Obrero Church, Eladio Dieste
Designed in 1950 built in 1956

Project during construction



Drawing showing the straight tangents at every point within the envelope.

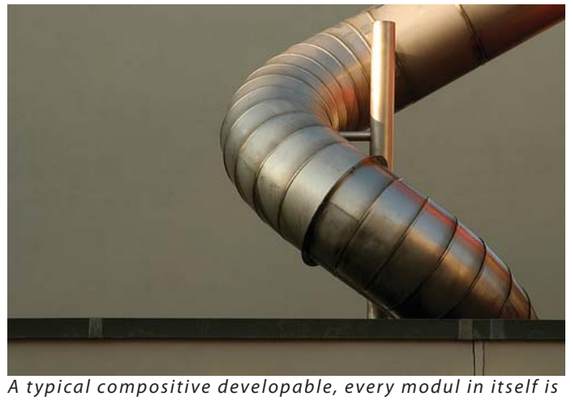
Restaurant at Xochimilco, Felix Candela, 1958

So it´s cheaper, that´s all?

The innovations within concrete (and later-on plastics) from the 50's-70's gave architects the possibility to finally move away from the pythagorean geometries we've been using since thousands of years in construction. The problem is that it's really hard to represent and create curved surfaces with a paper and pencil, so we need to make use of digitally driven techniques. The idea is nice but while a computer is able to show a perfectly curved surface on the screen, in real life it's much harder to obtain such a shape. Single curved surfaces is a **compromise** between flat surfaces and fully curved ones. You can design complex curved envelopes while remaining almost the simplicity of pythagorean geometries.

What is possible?

What is important to notice is that developable free-form envelopes can be subdivised in 2 categories: *"**Pure Developables**"* , which are envelopes of which the whole can be considerated as a developable form. Formwise you'relimited of the forms you can obtain.
And the second one, *"**Composite Developables**"*. Which are envelopes which in themself are not a developable surface but which are composed of developable surfaces.

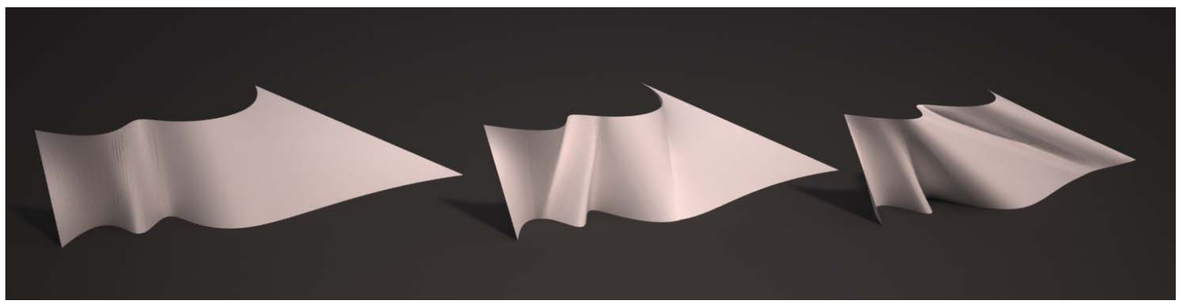


A typical compositive developable, every modul in itself is developable.

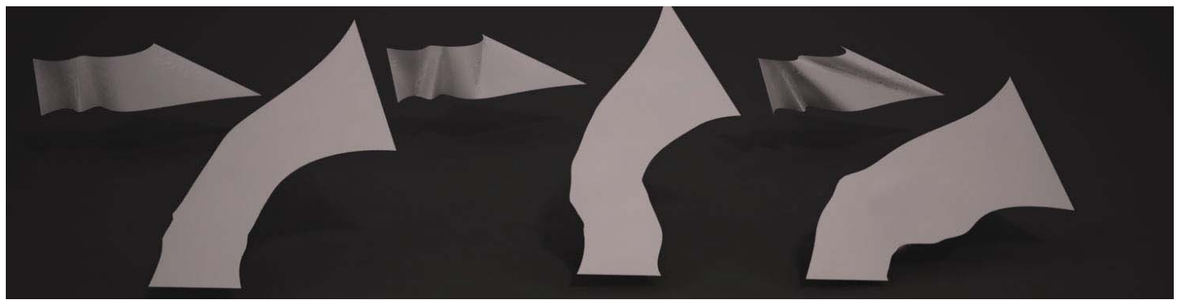
***Frank Gehry**, Experience Music Project. Pure developable forms.*

How to create them?

The easiest way to create developable surfaces is to "loft" 2 freeform rails together. However this will give you just A result, not the result. Between two rails there exist an inifinity of developable surfaces. In order to gain control of the loft command *"ruling guides"* need to be created. I've however not been able to find a way of creating them automaticly, so it's a time costing process.

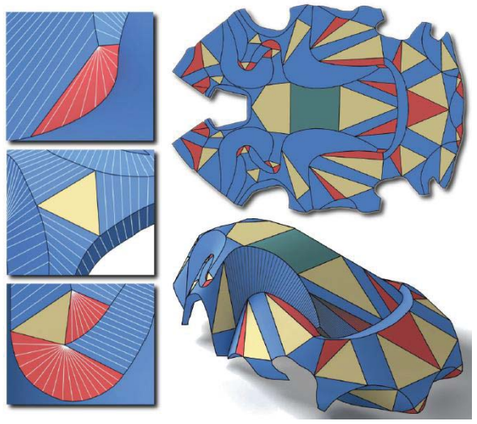


Three developable surfaces created each by identical lofting rails, however each surface has it's own ".ruling guides"

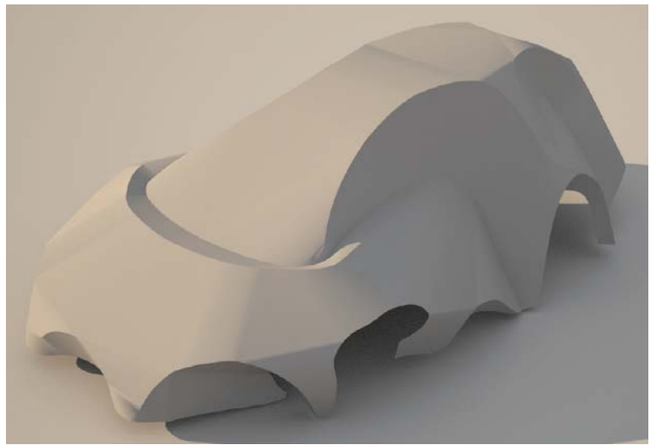


Unrolled surface of each variation.

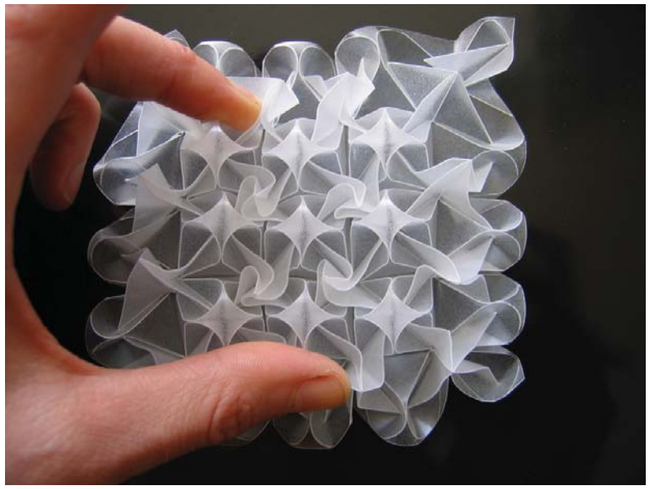
Paper Folding, a possibility?

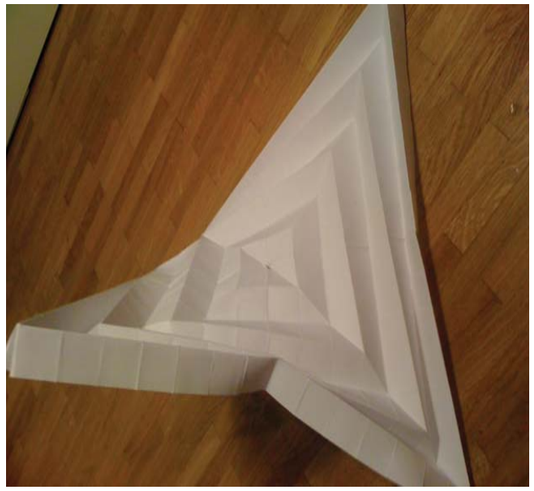


Origamis (paper folding) have been practised since more then 400 years. However only recently people started started to experiment with curved folding lines instead of straight ones. This innovation drastically changed the aspect of paper folding. It allows to obtain elegent single curved surfaces. This transition however made it much more difficult to create the origamis. By example it's almost impossible to obtain the forms only by hand. The folding lines have to be burned by a laser beforehand, and normal paper is often too weak for these forms. Due to these increasing complexities it takes a long research and find a single pattern. This might also be the reason why it's hardly possible to find any developed pattern to fold on internet.



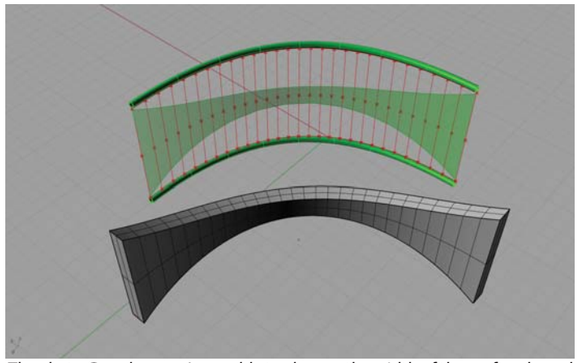
trying to work with paper folding, trying to recreate some of the fantastic examples which can be found on flickr. Handwise it's too difficult to recreate accuratly the forms. After contacting them they seem to use a laser cutter in order to weaken the paper exactlz





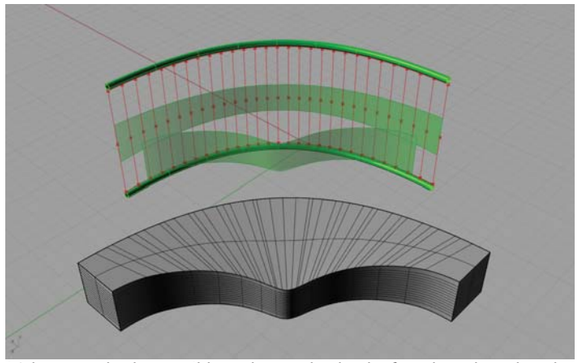
On the right another exemple of curved paper folding found on internet . On the left a personnal test of paper folding, with straight folding edges, even with this kind of model it can get very tought to create the origami without he appropriated experience.

Algorithmic Modelisation a necessity?

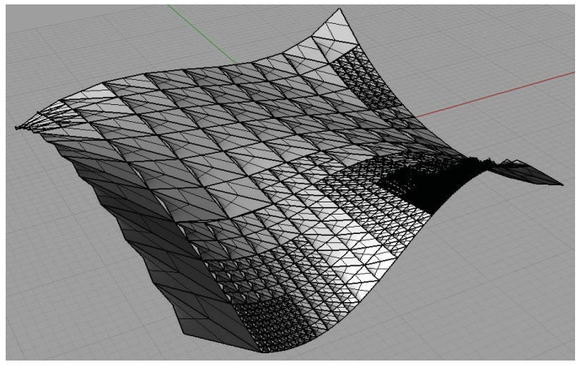


Thanks to Grasshopper I was able to change the width of the surface based on the intensity of the bend at a local point, creating a shape fully based on the surface properties

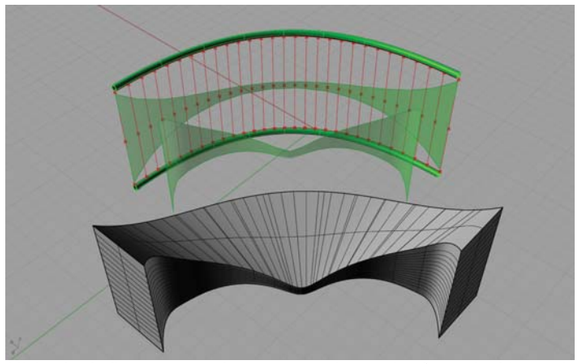
Creating a developable surface isn't complicated in itself. The simplest way consist of creating two curves and them lofting them together. To gather more control of the surface guiding lines can be used. Nothing more simple.
Things get complicated when you want to manipulate these developable surfaces or trying to work further with the properties of the surface, in order to find new forms.
Thanks to plugins, like Grasshopper or Rhinoscript we're able to work with the properties of developable surfaces, instead of just creating them. This allows us to gain acces to more complex forms.



It's by example also possible to change the depth of a volume based on the intensity of the curvature



This experiment by Rodrigo (Culagovski), subdivides the surface based on the curvature of it. More it's curved more it's subdivided



Mixing both diagrams together can create interesting forms. In this case it remains simple, because both curves are identical.

Frank O. Gehry

Weatherhead School,
Designed in 1999

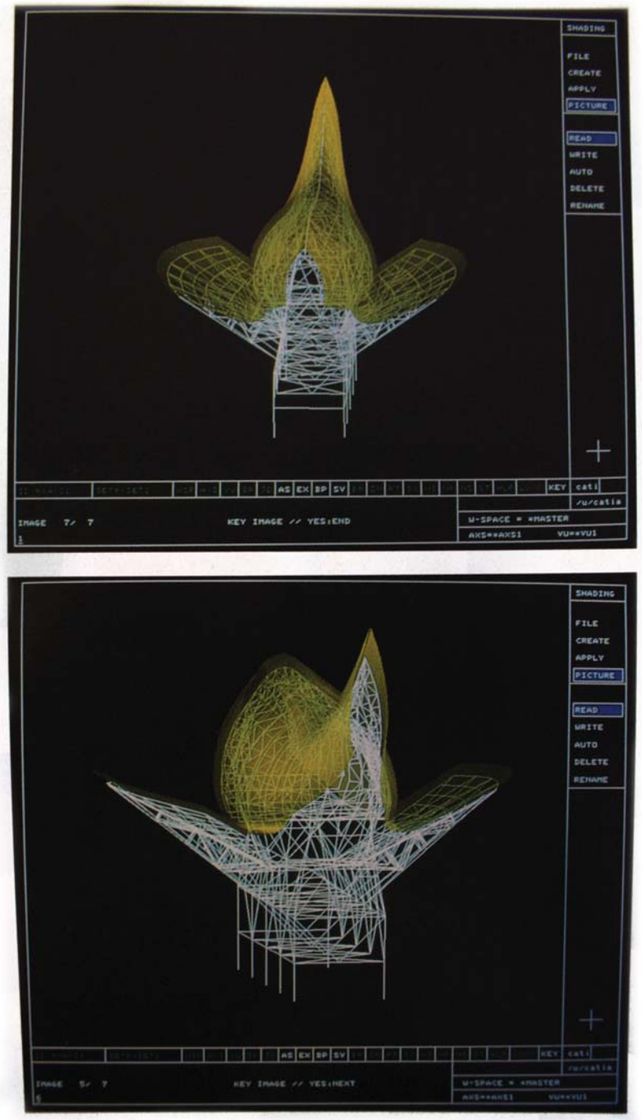
Guggenheim-Museum,
Designed in 1997

Guggenheim-Museum,
Built in 2006

Experience Music Project,
Designed in 2000

Who is he?

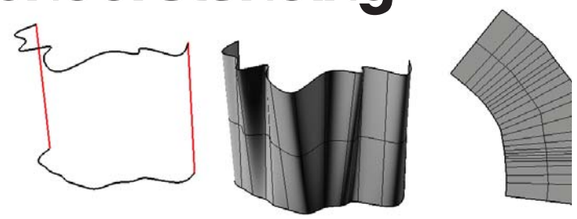
Frank O. Gehry is an architect known for his buildings based on deconstructivism. This new architecture style mainly focuses it's interest on the envelope form, which often seem unpredicable. He was one of the pioneer using computerized techniques with Dennis Shelden.



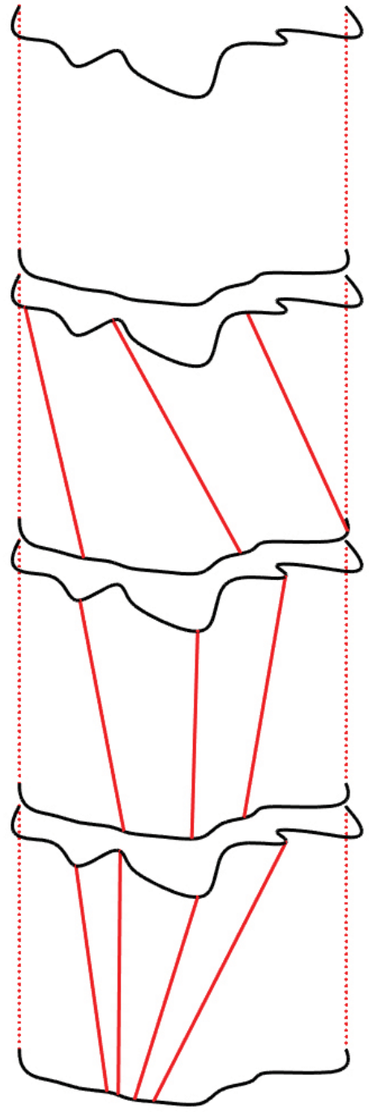
Gehry basic 3D modeling tools

Der Neue Zollhof **DusselDorf**
Built in 1999

First attempt of understanding



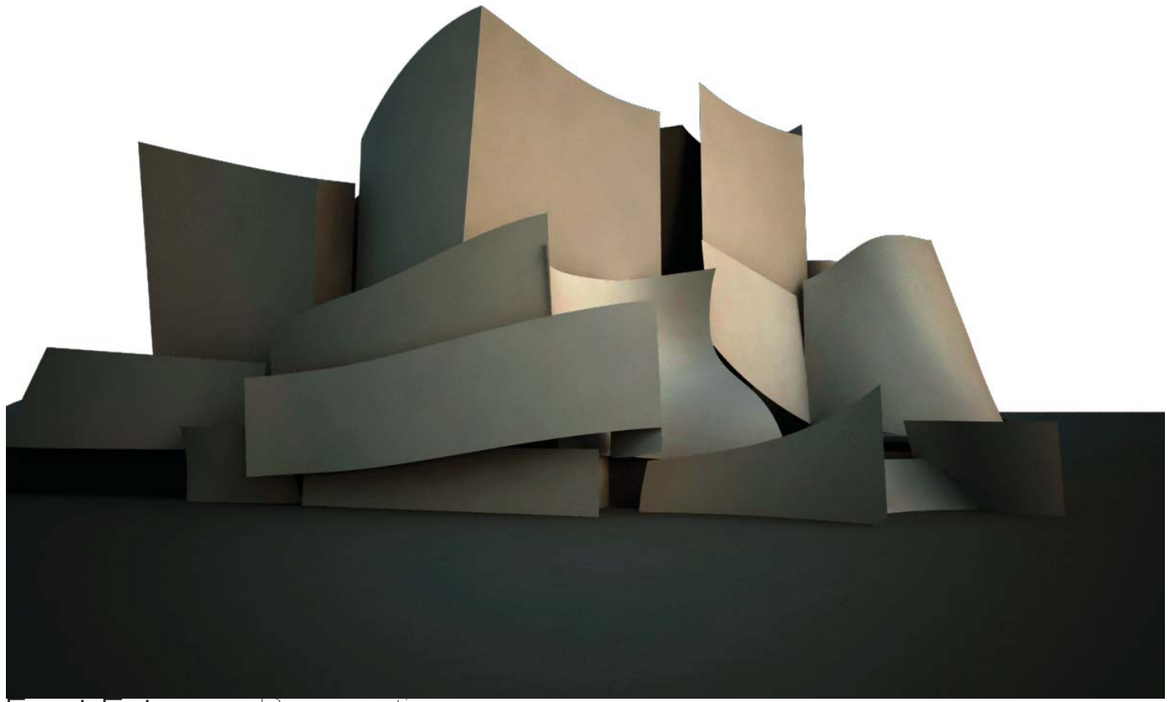
The shape of this building can be obtained by lofting two different curves together. Because of the fact that it's a curved surface it can be unrolled.



Guiding Lines

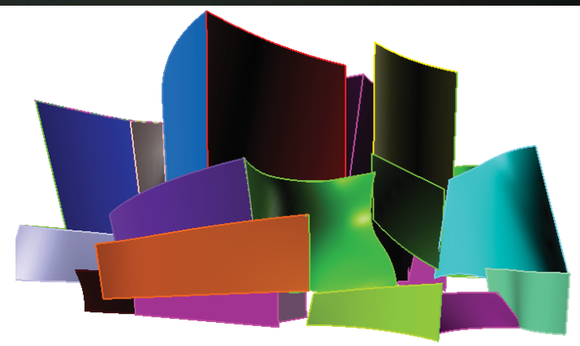
Thanks to guiding lines we gain more control of the lofted surface. The examples on the left side show multiple alternatifs of *Der Neue Zollhof*.
These four surfaces have been created thanks to a Grasshopper diagram which automates the process.

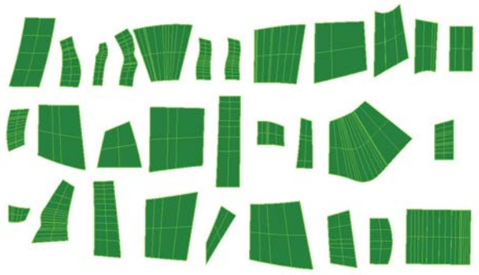
Frank O. Gehry, Walt Disney Concert Hall
1987-2003



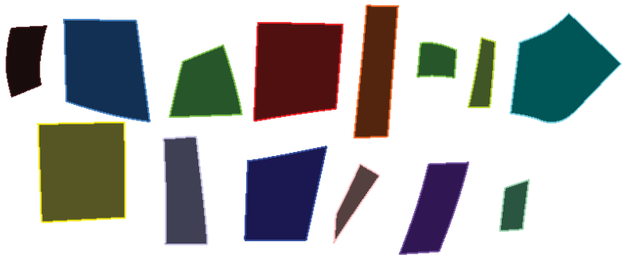
Front Entrance Perspective

70 Curves, guiding the surfaces

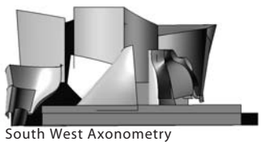




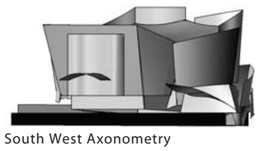
All Surfaces the unrolled



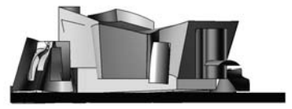
Unrolled surfaces of the front enveloppe



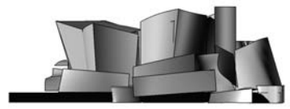
South West Axonometry



South West Axonometry

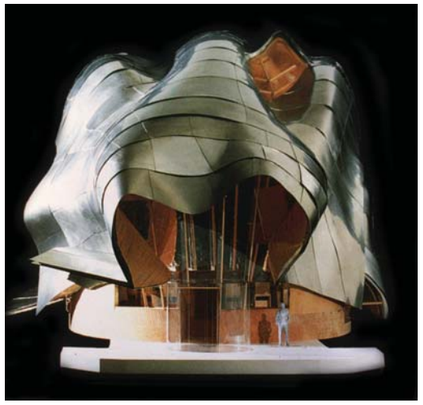


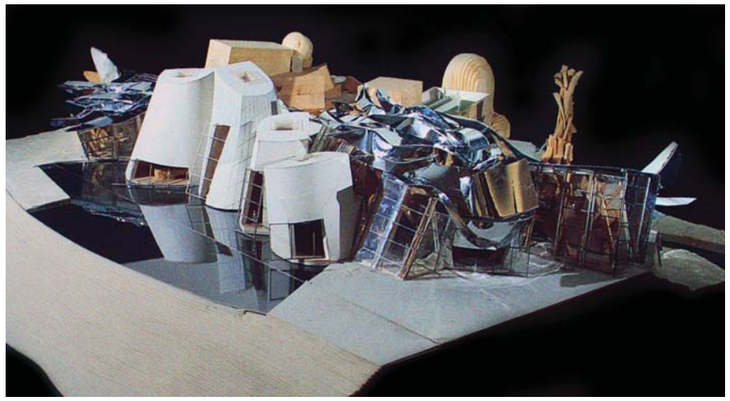
North West Axonometry

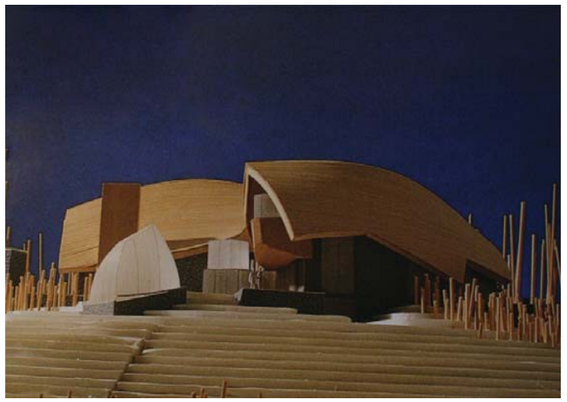


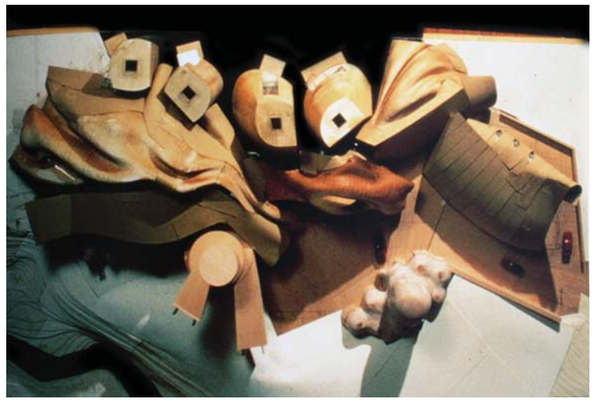
North East Axonometry

How to translate it in models?

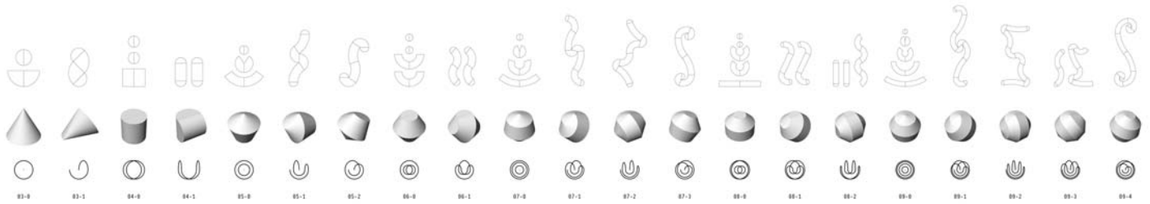








Different types of models using developable surfaces



Paper Folding might also be a solution but creating a folding pattern is more difficult then it looks

Like developable surface posseses a straight line within itself at every point, It might be a good opportunity to work with this property within making models itself, and expressing the ideas.

Sources

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