

# HOW VIRTUAL BECOMES REAL

Find structural form with Karamba  
Form-finding with “Large deformations” (G\_01.2)

Creative team

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## 0:00 SLIDES

### 1 cover slide

- In this tutorial, you are going to perform a structural form-finding with Karamba, a FE plugin for Grasshopper
- The shape you are going to obtain can then be discretised into a gridshell following the instructions provided in tutorial G01

## 0:14 6 slides on form-finding

- Before starting, just a brief introduction on the concept of form-finding
- Traditionally speaking, in architecture and structural engineering ‘form-finding’ identifies the process of designing optimal structural shapes by means of experimental tools, that is physical models, to simulate a specific mechanical behaviour
- The reverse hanging method is the oldest and probably most diffused form-finding technique – a physical model, made with elastic cables or membranes with no rotational stiffness, is first subject to gravitational forces to obtain a structural state of pure tension; such a form, which is called “funicular”, is then inverted to identify the mechanical compression-only situation
- Antoni Gaudí designed several buildings with the aid of this procedure. Rather known is the model he realised for the Church of Colonia Güell, in which two hierarchical orders of strings were used
- The Multihalle in Mannheim is another rather famous project, in which non-rigid nets were used
- Specifically for the form-finding of RC shells, Heinz Isler developed a technique based on suspension of wet pieces of fabric or membrane - the derived forms were then frozen and inverted
- Apart from the reverse hanging method, one can use minimal surfaces, pneumatic shapes or geometric shapes to generate structural form
- For further information refer to the chapter: *(Digital) form-finding* of the book “Algorithms-Aided Design”
- For the purpose of this tutorial you are going to focus on simulating the behaviour of hanging models by means of Dynamic Relaxation, using Karamba
- Now, let’s start

## 1:52 GRASSHOPPER

- First, let’s open the Rhino **Options** panel and make sure the **Units** are set to **Metres**
- Now you can draw the surface you will work on directly in Rhino, four-point surface
- You can import it in Grasshopper by **Right Clicking** on a **Surface** component and choosing **Set one surface**
- Use the **MeshBrep** component to mesh your NURBS base surface
  - o Use a **MeshEdges** component to visualise the edges of the mesh
  - o Let’s feed a **CustomMeshSettings** component to control the mesh parameters
  - o For instance you can set to 40 the resolution of the mesh feeding a slider into the inputs *min quad count* and *max quad count*
- Use the **WeaverbirdStellate** component to triangulate each quad face with both diagonals and avoid undesired asymmetries, as Karamba automatically triangulates the quad faces of a mesh using a single diagonal
  - o Remember to set the *distance D* to 0
- Use the Karamba **MeshToShell** component to transform the mesh faces into Karamba shell elements
- Now use the Karamba **Loads** component to apply a *gravity load* to the points
- Use the **NakedVertices** component to retrieve the edge points of your mesh and feed these into the **Support** component

- For the purpose of this tutorial, you can assume the structure is supported at the edges by fixed joints
- Tick all the *radio buttons* to constrain translations and rotations – this will prevent the structure from moving in rigid body modes
- Now use the **Assemble** component to build the Finite Element model and connect: **MeshToShell**, **Loads** and **Support**
- Use **LargeDeformation Analysis** to perform form-finding
- Also use **ModelView** and **MeshEdges** to visualise the output geometry
  - o When a *gravity load* is applied, this component iteratively simulates the behaviour of a hanging model
  - o You can set the *maximum displacement* to define the height of the form-found structure – use for instance 4m
  - o Now set the number of *incremental iterations*, which is 5 by default, to 100 – you can see that a higher value increases the model precision but also requires more computational time
- You can finally invert the direction of the *gravity load* to obtain the reverse hanging model
- To simulate a pneumatic form, just convert the load into a **Mesh-Load**
  - o This will allow you to orient the forces locally to the mesh and simulate a pressure

#### 4:44 SLIDE

- This is the end of the tutorial. In the support master file, you will find the refined Grasshopper definition, which is linked to the codes already developed in tutorials G01 and G01.1:
  - o To activate or deactivate this modulus, use the switch on the top left (**ValueList**)
  - o The **Surface** component highlighted in green is a placeholder for your input geometry
  - o The central part of the definition is the Karamba pre-processor
  - o The form-finding parameters are collected in the pink groups on the left
  - o Structural supports are defined at the model boundary by default. However, you can use the lower part of the definition to create custom openings along the perimeter
  - o This component performs form-finding
  - o On the top right, you will find the final geometry; since tutorials make use of NURBS surfaces, a custom cluster retransform the output mesh into a Brep

#### 5:39 END OF TUTORIAL G01.2