# Virtual Simulation Lab: Introducing the Virtual Goniometer (VIRGO)

In previous posts, we have described the capabilities of the Experimental Research Lab. Today, we welcome you to the Virtual Simulation Lab and VIRGO, the Virtual Goniometer.

In Figure 1, we show a schematic illustration of the VIRGO goniometers. In order to create high-resolution polar responses, we are using a large number of virtual microphones than are used experimentally.

2D:

- Number of microphones: 180
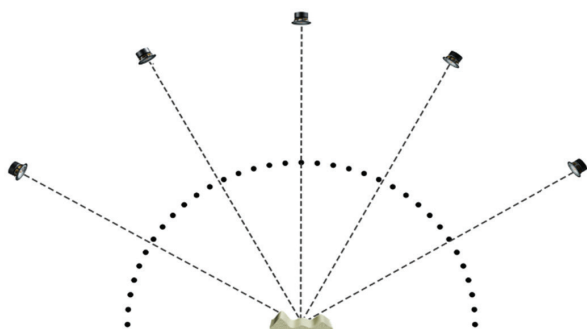
- θ spacing: 1°

3D:

- Number of microphones: 4,295
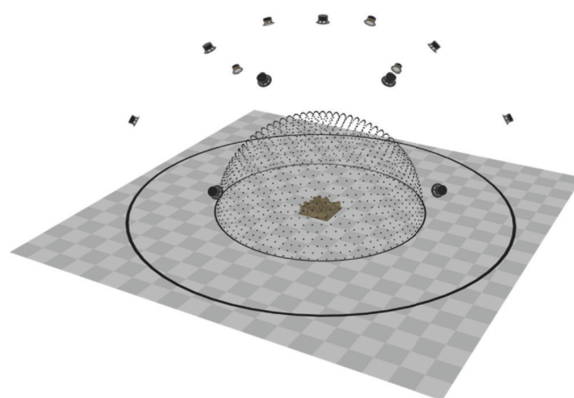
- θ and ϕ average spacing: 1.6°

Figure 1. Left: 2D virtual goniometer; Right: 3D virtual goniometer

The 2D goniometer uses 180 microphones with a 1° angular resolution and 5 source positions at 30°, 60°, 90°, 120°, and 150°. The 3D goniometer utilizes 13 source positions, specified by ISO 17497-2 and 4,295 microphones with a 1.6° angular resolution in azimuth and elevation ϕ and θ. *The checkerboard base is not used in the calculation.*

Position Number	Elevation θ	Azimuth ϕ
1	0	-
2	30	0
3	30	60
4	30	120
5	30	180
6	30	240
7	30	300
8	60	0
9	60	60
10	60	120
11	60	180
12	60	240
13	60	300

Figure 2. 13 3D goniometer source locations

In order to calculate the scattered polar responses and diffusion coefficient, the surface to be simulated is meshed (discretized) with a program called GMSH. For a given frequency, the maximum element size must be at least 6 times smaller than its wavelength. In Figure 3, we illustrate a triangularly mushed topology showing discretized mesh Elements and Nodes.
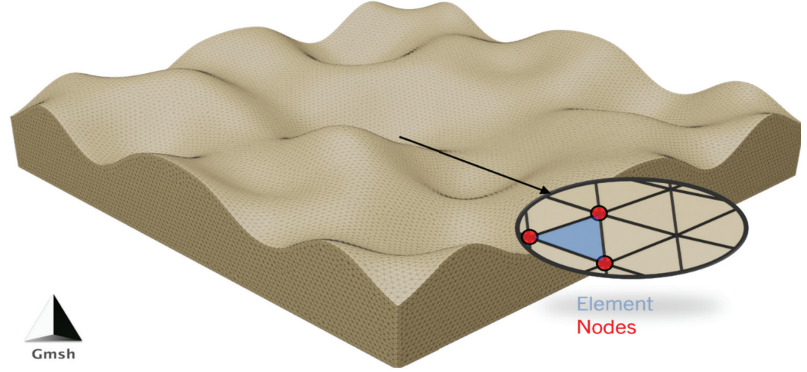

Figure 3. GMSH triangular meshing program.

In Figure 4, we show a frequency domain wave model based on the Kirchhoff-Helmholtz integral equation over the surface, S, using a 3D Green's function. The incident pressure is represented by a monopole point source.

$$G(\vec{r}, \vec{r_s}) = \frac{e^{-jk|\vec{r}-\vec{r_s}|}}{4\pi|\vec{r} - \vec{r_s}|}$$

$$c(\vec{r})p(\vec{r}) = p_i(\vec{r}) + \int_S p(\vec{r_s}) \left[\frac{\partial G_k(\vec{r}, \vec{r_s})}{\partial n(\vec{r_s})} - jk\,\beta(\vec{r_s})\,G_k(\vec{r}, \vec{r_s}) \right] dS \quad,$$

$c(\vec{r})p(\vec{r})$ is the pressure at point $\vec{r}$ modified by $c(\vec{r})$, which depends on the location on the interior of the boundary, the exterior of the boundary or on a boundary element. p_i is the incident pressure, $p(\vec{r_s})$ is the pressure on boundary element S, j is the square root of -1, k is the wavenumber and β is the admittance on boundary element S.

Figure 4. Kirchhoff-Helmholtz integral equation, with the 3D Green's function, G

In the next post, we will compare the VIRGO simulation of a hemicylinder with an experimental measurement.

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