Sculpture Inspired by Connectivity in Nature

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Abstract

My early work consisted of sculptures for public art cast in bronze, stainless steel and iron using the lost wax method. The subject matter in my work was primarily the human figure. My interest evolved in abstracting the human form as a structural aesthetic to engineer interconnected groups of figures to define spheres, geometric primitives, and random lyrical configurations. This transition lead to my most recent preoccupation to explore digital technologies such as CAD-CAM, rapid prototype and mathematical 3D modeling software applications to create purely mathematically generated objects that reflect the connectivity observed in nature and to reinterpret the geometry into new figurative objects that incorporate mathematical continuity.

Connectivity in nature has a striking presence re-appearing time-and-again evoking bubble foam structures, neural-networks, root systems, subatomic particles, crystallographic structures, in essence everything that exists in nature. From our milky-way centered point of view the universe has an estimated observable diameter of 93 billion light-years; conversely the scale of string theory is on the Planck length of $\boldsymbol{10^{-35}\ m}$. Why is it that these structures persist with an uncanny frequency suggesting connectivity of all forces and all matter regardless of how small or large they may be? If so, do we really understand the dynamics of the "comprehensibility" of the universe as a unifying force? What exactly is the connective glue that bonds everything together? The answers to these questions are beyond the scope of this paper yet I will intuitively delve into the realm of science and mathematics to convey my creative process.

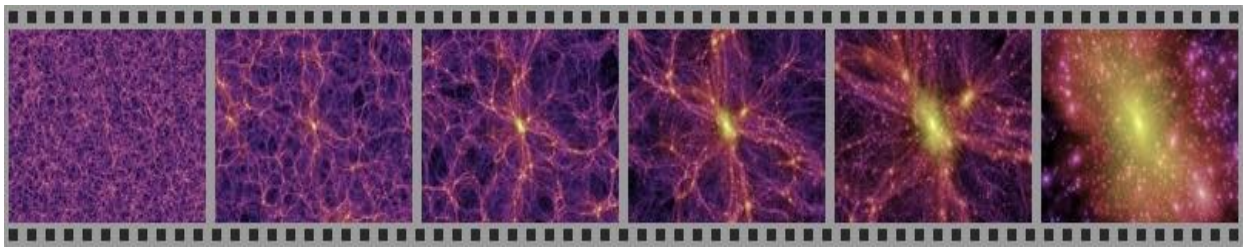

Figure 1: *Dark Matter/Dark Energy Mapping*

Early in my life as a sculptor and as a mathematically inclined lay-person I became conscious of working with the medium of the human form as a metaphor for nexus, as in Synergy II (Figure 2). Little did I know while creating these series of interconnected lattice works of human figures, I was bridging the boundaries between reality and abstraction. Keep in mind that at the time, pre-digital 1980s, I was in the transition of merging the artistic with the scientific in my thought process. My goal in designing *Synergy II* was to populate simple space by engineering a universal binding structure of the human figure as a construction element, expressing the notion that the whole is greater than the sum of its parts, thus a synergy.

The advent of 3D computer modeling opened up a new realm of possibilities through generative, mathematical, transformative, and scanning techniques true to form, that convey innumerable ways to get "things" into the computer. The physical limitations between mind and matter had been unlocked. Stephen Hawking maintains that even though his body is almost completely paralyzed his mind is completely free unencumbered by the trappings of his physical body although he has a capability of typing merely four words per minute! We are but 21st-century cerebral sapient beings trapped within the bodies of Cro-Magnon

Figure 2: *Synergy II- bronze & granite (20'x10'x8')*

A further contributing element to my sculpture in unifying space is inspired by centroidal Voronoi tessellation (CVT) named after Georgy Voronoy, founder of the Geometry of Numbers. CVT is defined as the partitioning and decomposition of three-dimensional space into regions so that all locations within any one region are closer to their centroid than any other centroid implying further recursive partitioning. The generating point of each Voronoi cell is its center of mass of a convex envelope (Figure 3). The accompanying digital sculpture was generated using algorithms applied to a dodecahedron in a random centroidal decomposition of the Platonic solid. Instead of treating the convex envelope surface of a dodecahedron, CVT partitions the interior encompassed by the surface thereby considering the intrinsic aesthetic of its spatial dynamics.

To further process the polygonal object I utilized a Laplacian smoothing technique referred to as *digital pixel blasting* of a polygonal mesh that was meticulously subdivided and decimated. Worn away by erosion in the same manner pebbles become smoothed over time as the sea grinds rocks together by ocean waves tumbling back and forth with the ebb and flow of tides thus becoming smoothed and rounded.

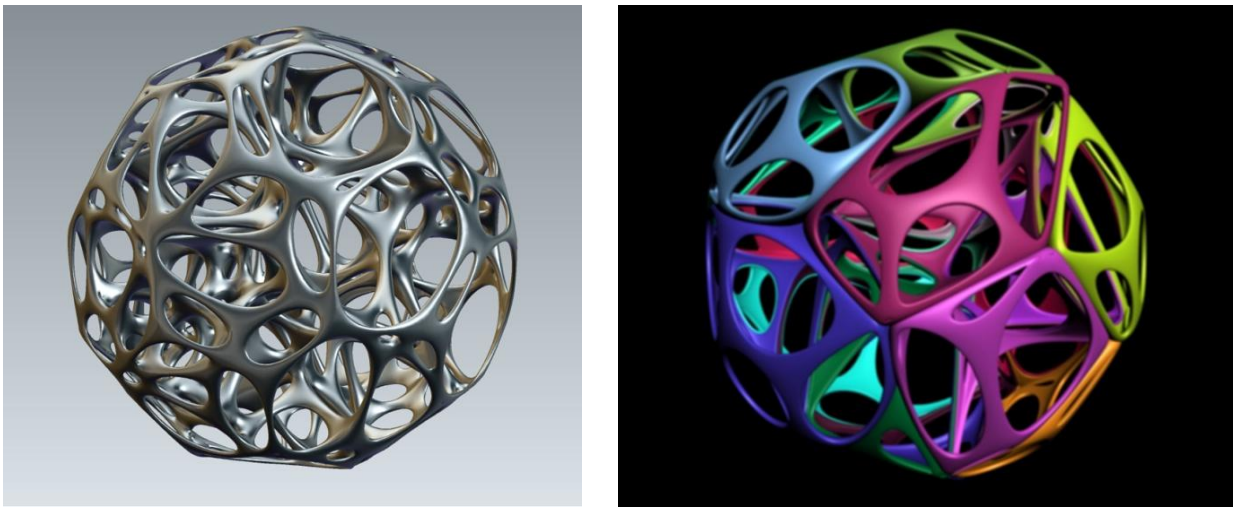

Figure 3: *2Voro-Dodecahedrons*

Figure 4 is an *isa* crystallographic digital sculpture; a random mass of an *isa dodecahedron* (net identifier-signature) bonding cluster reduced to its elemental borders or *Plateau border* to create a bubble like structure that suggests the connectivity of dark matter mappings of galactic clusters.

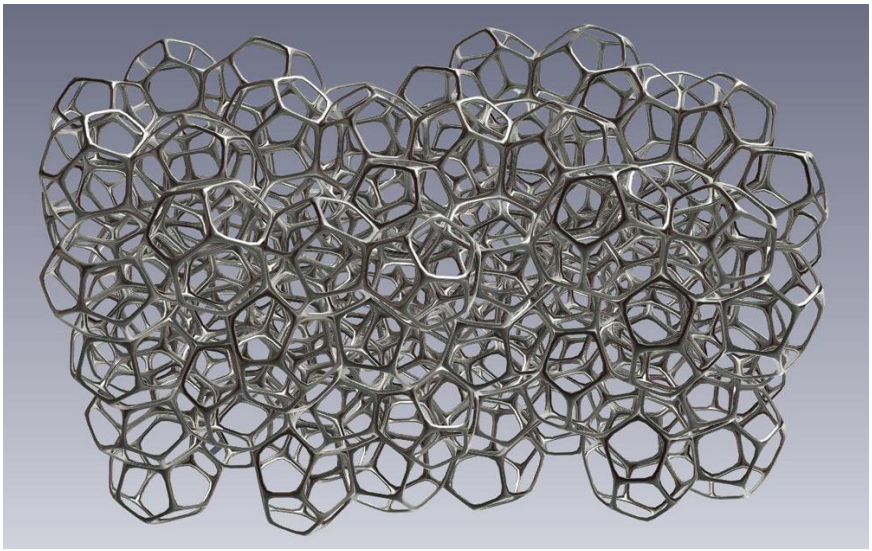

Figure 4: *isa-Crystallographic Plateau Borders*

The mathematics applied to generate the source code for Calabi-Yau (Figure 5) I found puzzling enough that I was compelled to probe deeper into the method for defining the elasticity and malleability of applied mathematical physics. The complex function for instance: $z = x + iy$ or in Euler's formula expressed as a trigonometric function: $e^{ix} = cos(x) + i\ sin(x)$, we apply in the theory of functions of complex variables to calculate the fiendishly yet elegantly mathematical objects like Calabi-Yau manifolds, Kahler manifolds, tensor bundles, Hilbert spaces, and superstring theory, fundamental in unifying the disparity between the infinitesimally small with the astronomically large with respect to the connectivity in multi-dimensions. Specifically, Calabi-Yau is a static representation of a super symmetry paradigm for the higher dimensionality projection of space surfaces with respect to time. They are without a doubt enormously intriguing as sculptures. The mathematician Bernhard Riemann in seeking to prove

Euclid's famous parallel postulate deduced with his revolutionary concept: higher dimensions within the curvature of space. Riemann working with well established Euclidian geometric conditions, *a priori* and in the process of attempting to prove its validity, a new enlightened theory evolved namely, hyperbolic and elliptic geometry.

In computational 3D graphics the subtle yet fundamental distinction between the implicit function: ***f(x, y, z) = 0***, and an explicit/parametric function: ***x = f(u, v), y = g(u, v), z = h(u, v)***, is that an implicit statement is limited to planes that do not intersect neatly and the resultant polygonal mesh is not uniformly ordered. The approximation of implicit isosurfaces however, defined by way of Cartesian coordinates, does allow for exquisite level set minimal surfaces. Implicit expression articulates space whereas the parametric expression defines a surface in space. Although the parametric function allows the independent variable to express complex functions in separate yet combined arguments and so the independent variability of a function and conjugation of complex surfaces of 3D parametric source code is ideal for computational sculpture (Figure 6).

Figure 5: *Artist with Calabi-Yau- N=6 Dimensions, rapidprototyed SLA (28"x28"x21")*

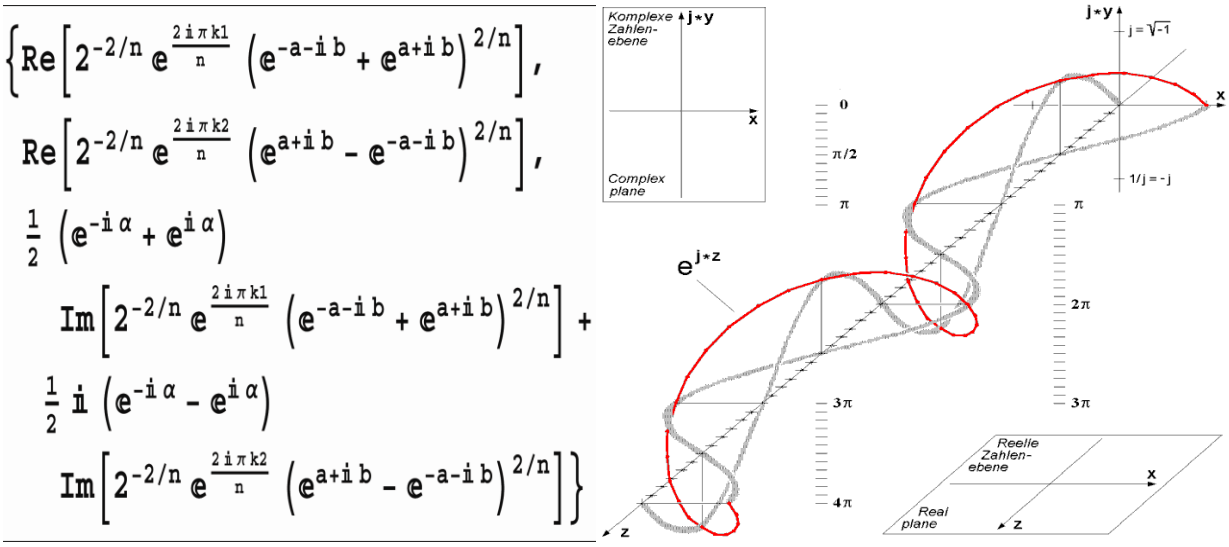

Figure 6: *Calabi-Yau: Trig-to-Exponent, Complex Plane illustration*

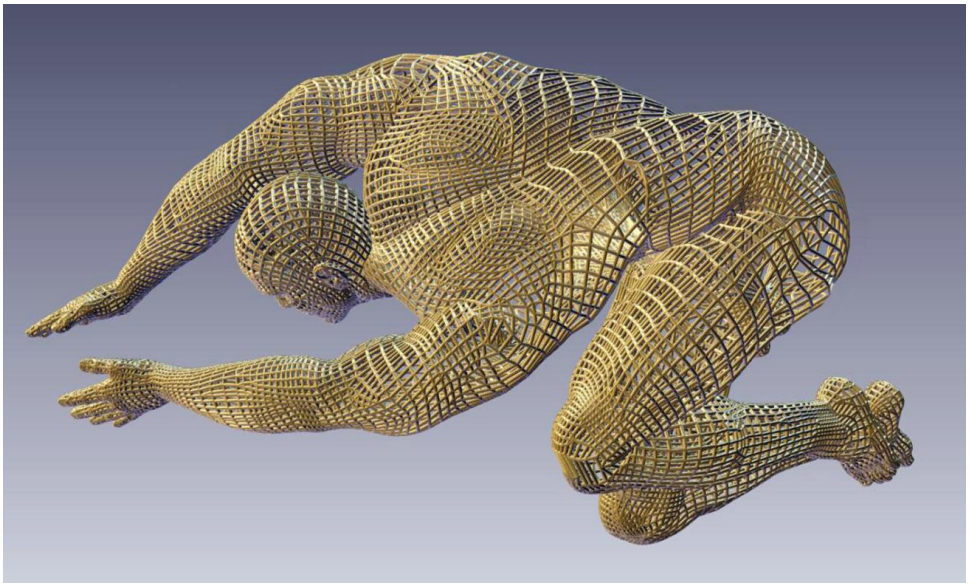

Figure 7: *Floating Male, digital 3D rendering w/lattice quadrangle polygons*

Once the numerical coordinates of a polygonal mesh have been generated, each polygon edge is transformed using surface modifiers into a faceted latticework to create a cage-like effect as in (Figure 7). There are many 3D applications to achieve this result: Maya, 3DMax and Blender to name a few. The number of edges of a polygonal mesh is determined by the specific software that generates the 3D format extension, (e.g., .obj, .stl, .3ds, .vrml, .off, .ply, .dxf). In **(**Figure 8) a quadrangle .obj generated Wavefront format, has the flexibility to shape a three or more *n-gon edge* faceting. STL (.stl stereolithographic*)* on the other hand is restricted to triangulated polygons (Figure 12) and is essential to the end result of most CAD-CAM processes.

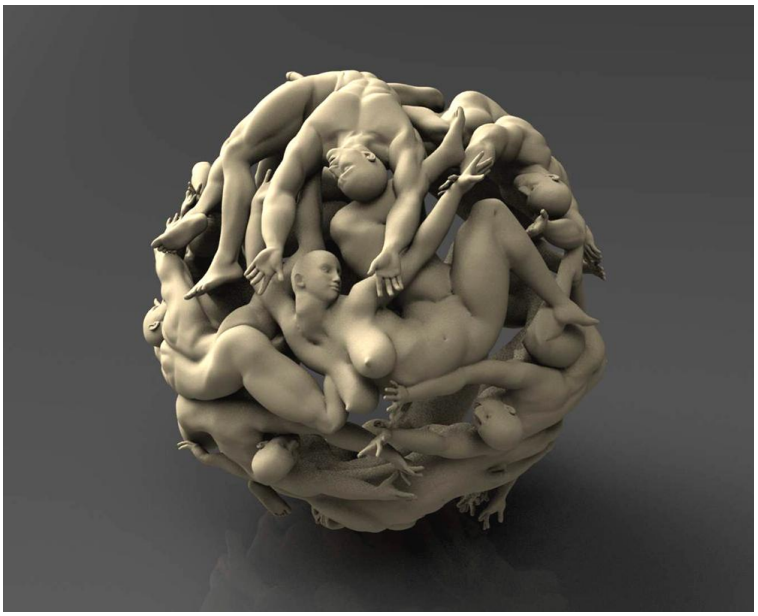

Figure 8: *Anthroshpere III, digital rendering*

Figure 9: *Arbor Cosmica – cast stainless steel, 8X11 (pre-digital)*

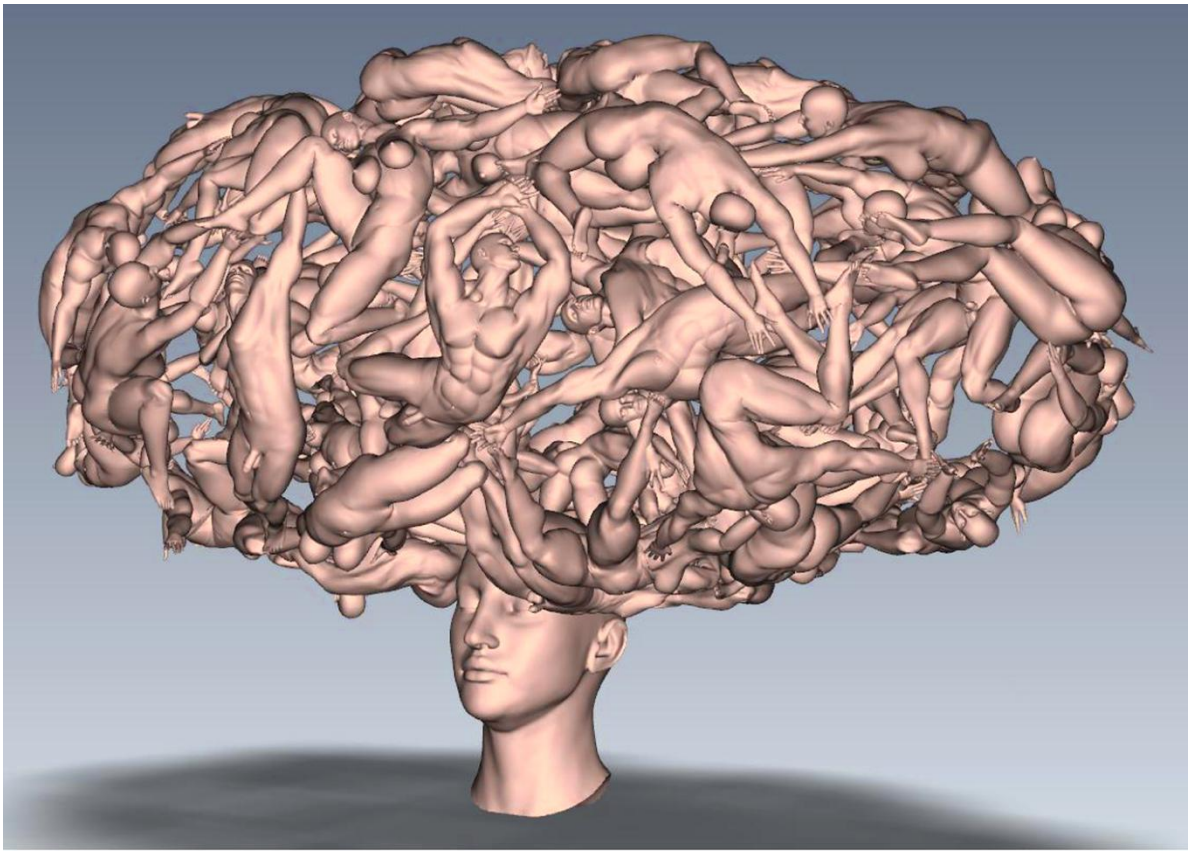

Figure 10: *Cosmic Event – digital 3D sculpture*

Conclusion

In complex dimensions, as it relates to the sculptor, the conjugation of real and imaginary planes expressed alphanumerically is compatible to eliciting the unlimited *plasticity* of space. Figure 9 illustrates the difference between pre-digital and digital influences in my work. As a sculptor I find this mathematically inspired transition to 3 dimensions enormously intriguing as in an amorphous mound of clay that has an infinite mutability potential and in essence everything: in reality, in the mind and in the universe (Figure 10).

We as artists have this infinite mutability option programmed into us genetically and can retrieve it with the utmost agility. It is a means to bridge systems of inventiveness to higher dimensionalities. Combining art and science is similar to reconciling elliptic curves with modular forms, or relativity with quantum. Who better than the artist/scientist to interpret the works of Fermat, Euler, Riemann, Voronoi, and Euclid?

"If the doors of perception were cleansed every thing would appear to man as it is, infinite.
For man has closed himself up, till he sees all things thro' narrow chinks of his cavern."

William Blake's
The Marriage of Heaven and Hell

By following this thread of intuition I have been looking at the big picture… a kind of artistic TOE (Theory of Everything); the binder that glues everything in the universe from the vast spaces to the infinitesimally small spaces that exist in string theory. As it turns out, many of these exquisite surfaces are elegantly representative of the physical and discrete laws that exist in our day-to-day human scale experience. Utilizing the computational techniques of CAD-CAM and rapid-prototyping I can create hand-held 3D printings in direct stainless steel as well as larger human scale versions. The "Human Sphere", or Anthrosphere (Figures 8, 10), was the transitional piece that led me to investigate the topological surfaces, nodal level set surfaces and higher dimensional spaces.

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[10] William F. Duffy, *Cosmic Event – digital 3D sculpture*, Baltimore, MD 2000
[11] William F. Duffy, *Crouching Female Figure,3D-polygonal mesh* , Baltimore, MD 2011

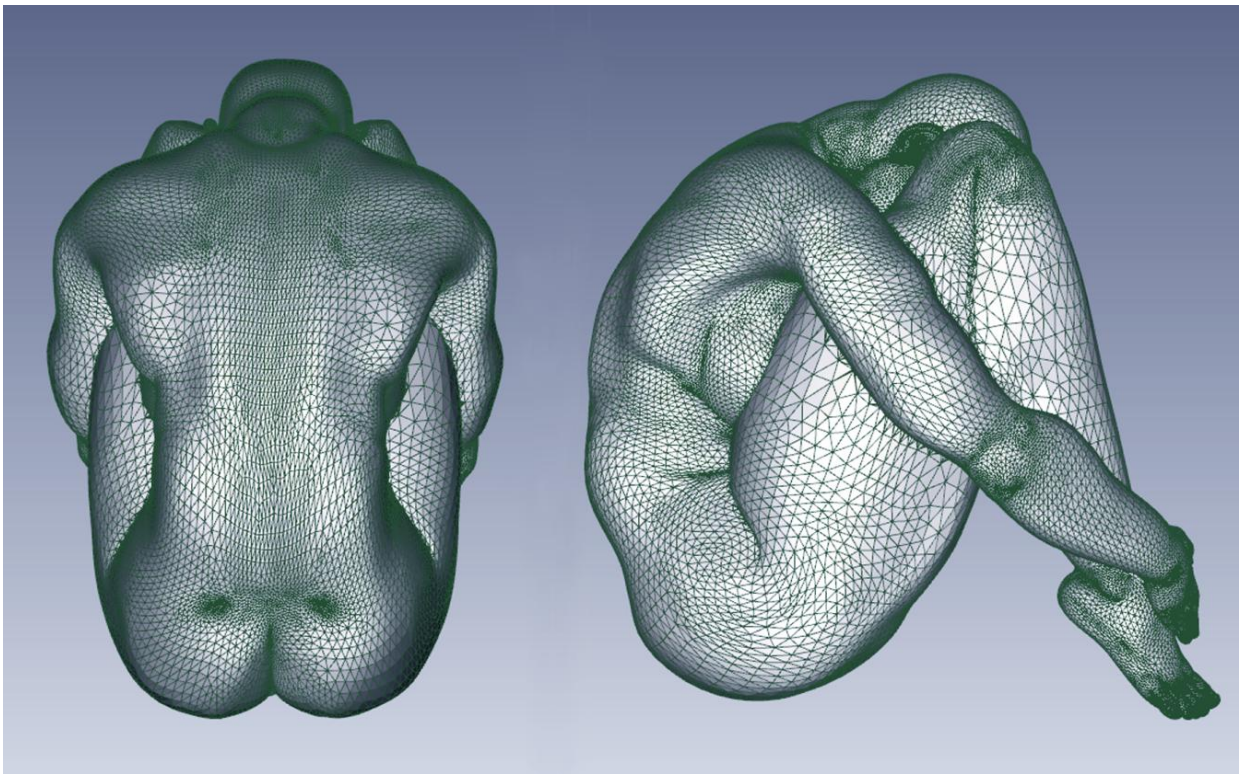

Figure 11: *Crouching Female Figure, w/3D-polygonal mesh rendering*