Geodesic Frame for National Stadium JAPAN

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Design Concept

Geodesics

A geodesic is a generalization of the notion of a "straight line". Geodesics can be found by solving the variational problem of the geometric energy. For the structural engineering, straight members in a euclidean space are often used for both manufacturability and constructibility. However, the notion of a "straight line" is more significant for the mechanics or structural rationality.

I propose geodesic frames by using geodesics for structural frames as the placement problem of structural members. Geodesic frames are "straight members" on a two-dimensional manifold in the three-dimensional space. A solution of form-finding minimizes the volume of structural members and the total axial load path, in the given boundary conditions.

I suppose that freely controlling a space/manifold, and the form-finding in these spaces is one of the new possibility for the next generation of spatial structures.

Geometry / Structural Mechanics

Geodesics can be found by minimization of geometric energy. Geometric minimization is closely related with structural minimization. As shown in Stromberg et al.[1], The minimal volume problem can be written as follows:

$$\min_{\mathbf{x}} V = \min_{\mathbf{x}} \frac{1}{\sigma} \sum |F| L \qquad (1)$$

where $\mathbf{x}$ is a design variable, σ is a constant which represents the allowable stress, L represents the length of the members and F the internal forces of the members. Therefore, in feasible solutions, the minimization of structural member length with a constant cross section is equal to the minimization of the total axial load path.

I apply two form-finding problems for a curved surface and geodesics. The sum of squared length as the geometric energy is used for each form-finding problem.

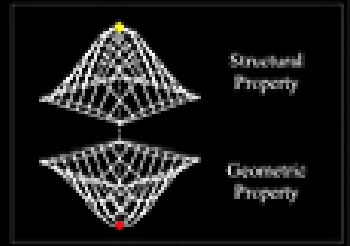
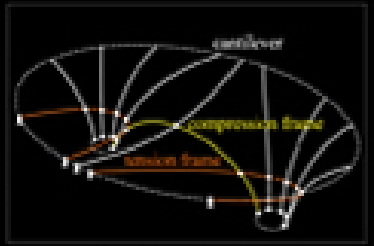


Illustration of solution space

[1] L. L. Stromberg, A. Beghini, W. F. Baker, E. H. Paulino Topology optimization for braced frames: Combining continuous and beam/column elements, Eng Struct 37,106-124, 2012

Structural Diagram

In a process of a structural design, we need to comprehend the flow of internal forces, and transfer the forces to supported nodes. In this proposal basic roles (compression, tension and cantilever) of structural members with a vertical load are given as shown in the right side figure. The form of structural member is found by solving the form-finding problems. The decision of the initial setting, for example surface boundaries and two vertices in the geodesic search, is important. I apply the static structural analysis by using FEM to the result of the form-finding, and confirm safety of the structural form.



Structural diagram