CONSTRUCTIVE TOPOLOGICAL DOMAIN MODELING FOR COMPUTATIONAL ENGINEERING

W. Gerstle[a] and **P-Y. Cheng**[b]

[a]Professor, [b]Graduate Student
Department of Civil Engineering
University of New Mexico
Albuquerque, New Mexico 87131
[a]gerstle@unm.edu, [b]peiyuan@unm.edu

Computational engineering demands that physical models be represented as mathematical initial- and boundary-value problems, which are then solved using approximate computational methods. In the early days of computational engineering, the domains of the boundary value problems were often represented using finite elements, and boundary values were described as equivalent nodal loads. However, a pure finite element description does not provide sufficient information for problems to be automatically refined for convergence studies.

In more recent years, computational engineering frameworks have become geometry-centric. In geometry-centric computational engineering, constructive solid models and boundary representation models of the geometry are first developed, and then, almost as an afterthought, the material properties are applied to the solid domain and boundary values are applied to the various boundaries of the domain. This has proven problematic, as most solid models do not provide adequate coordinate system support to apply generally varying material properties and boundary values. Furthermore, constructive solid models are not sufficiently general to describe a wide variety of topological and geometric domains that actually arise in engineering problems.

In this paper, we propose a topology-centric metamodel for computational engineering. It is a topological modeling method that allows not only quite general topological modeling, but also promotes geometric and physical modeling, by providing a topological base space for the definition of structured finite element meshes, fields, and the definition and solution of boundary value problems. We name the method constructive topological domain method (CTDM) [1]. In this method, primitive topological domains (PTDs), each possessing a natural coordinate space, are combined in multiple n-dimensional Cartesian coordinate spaces, called charts, using generalizations of Boolean set operations, to create constructed topological domains (CTDs) capable of acting as the base spaces of fiber bundles. The charts are glued together to create an atlas, within which the CTD is defined. The fiber of the bundle may describe, in addition to geometry, physical fields like density, stress, and temperature.

Structured or unstructured finite element meshes may be defined upon each of the PTDs from which the CTD is constructed, enabling the definition and solution of boundary value problems, thus avoiding the difficult and messy problem of creating a single finite element mesh to represent the entire CTD. A modified finite element method, to handle the individually meshed PTDs, is described. The boundary conditions may be specified as analytical or as finite element-based fields upon each of the PTDs.

The CTDM appears to be a promising approach to robust mathematical and computational modeling of physical objects. Convergence studies may be conducted with no ambiguity as to what problem is actually being solved. Simple examples are presented.

References

[1] W. Gerstle, "Toward a Meta-Model for Computational Engineering", *Engineering with Computers*, Vol. 18, Issue 4, pp 328-338, Springer-Verlag, London, 2002.