# Past and current research contributions

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# Overview

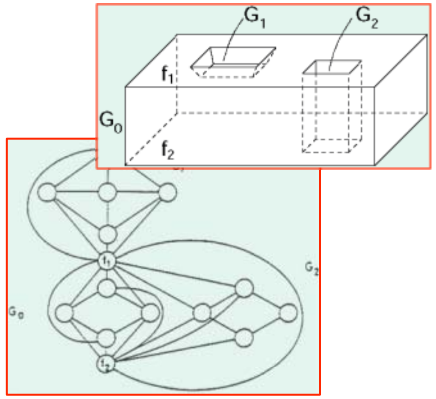
- Past contributions to **shape representation, processing** and **analysis**
  - Feature-based modeling and analysis
  - Multi-resolution geometric modeling
  - Non-manifold geometric modeling

- Current research and challenges in **topological data analysis**
  - Homology-based descriptors for shape understanding
  - Topology-based visualization for interactive analysis
  - Scalability to big, multi-dimensional data

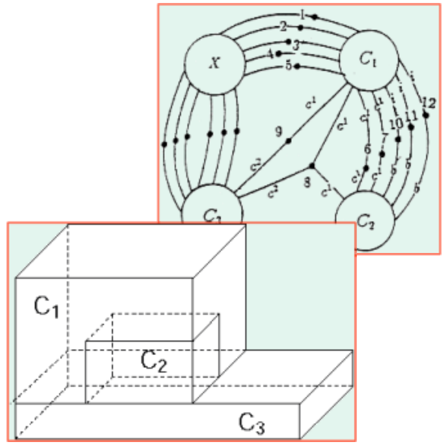
# Feature-based Modeling and Analysis

## Shape representation and analysis

- **Feature-based boundary representation** of solid objects [ACM SIGGRAPH, 1985; ACM TOG, 1988]
  - object decomposition into form features
  - graph-based representation



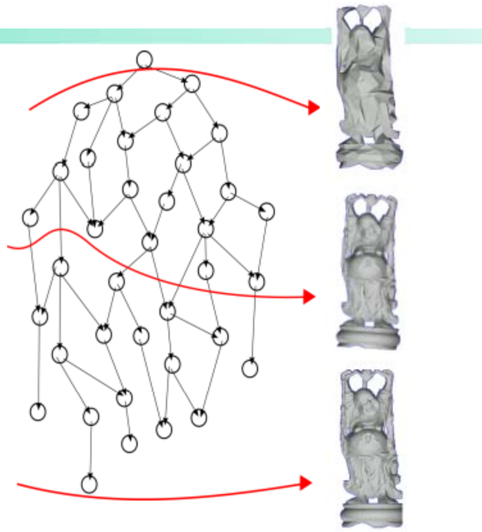

- **Form feature detection and understanding** [ACM SoCG, 1987; IEEE PAMI, 1989]
  - graph-based approach
  - detection based on the analysis of the graph k-connected components



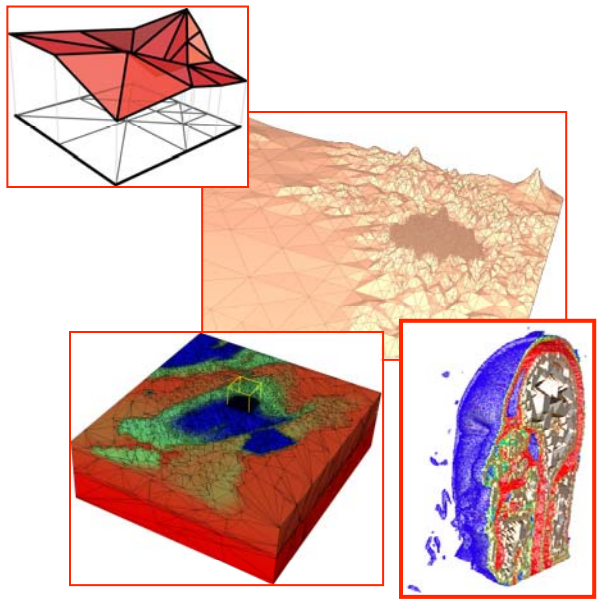

- Application to product design, analysis and manufacturing

# Multi-resolution Geometric Modeling

## Shape representation and processing

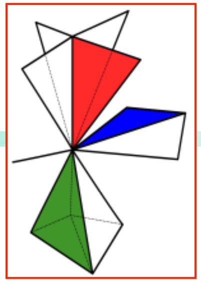


- **Hierarchical mesh-based representations** for terrains, 3D surfaces, 3D scalar fields
  - geospatial data processing, computer graphics, scientific data visualization
  - emphasis on geometry processing
- **Terrain and surface modeling**
  - Delaunay Pyramid [CG&A, 1989]
  - Hierarchical TIN (Triangulated Irregular Network) [ACM TOG, 1995]
  - Multi-Tessellation (MT) [IEEE VIS, 1998]
  - Sparse Terrain Pyramid [ACM SIGSPATIAL, 2008]
- **3D scalar field modeling**
  - Multi-resolution unstructured volume meshes [IEEE TVCG, 2004]
  - Diamond-based tetrahedral hierarchies [IEEE TVCG, 2009 and 2010]

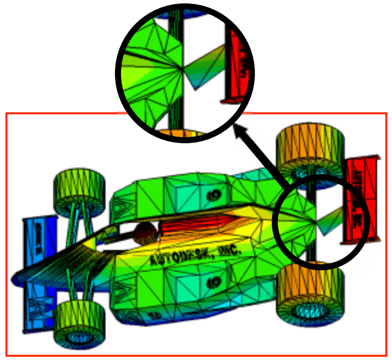


# Non-manifold Geometric Modeling

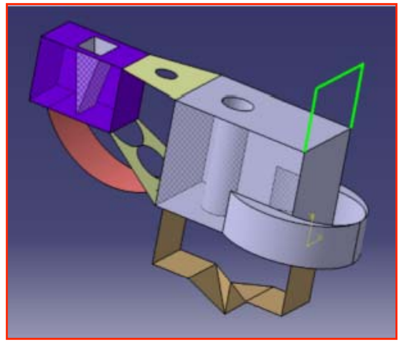
## Shape representation and analysis



- **Decomposition of non-manifold objects** into nearly manifold components [SMA 2003; GM, 2003; CAD 2011]
  - dimension-independent and unique
  - applications:
    - decomposition-based data structures
    - reasoning on non-manifold shapes

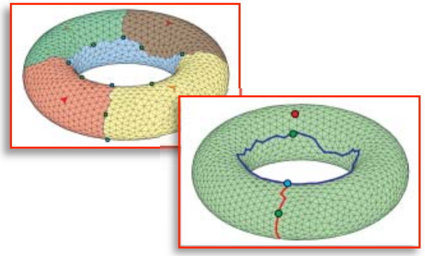


- Compact **mesh-based representations** for **non-manifold** objects
  - connectivity-based and spatial data structures [SGP, 2003; CAD, 2004; ACM SIGSPATIAL, 2011; CGF, 2013]
  - data structures for arbitrary dimensional simplicial complexes [SGP, 2004; C&G, 2011]

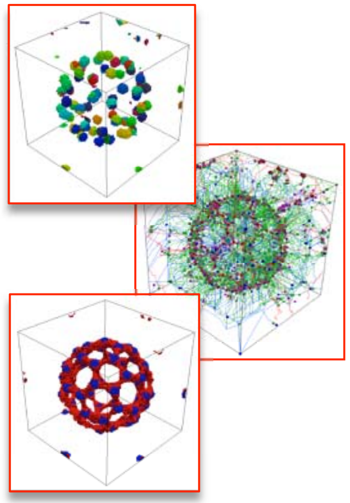


# Topological Data Analysis

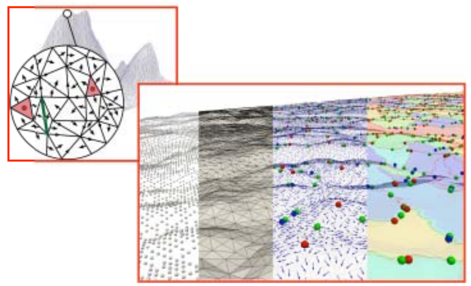
## From graph-based to topology-based shape analysis



- A collection of combinatorial tools rooted in **algebraic topology**
- **Persistent homology**
  - study the homology of a shape through a scalar function defined on it
- Compact and robust **topological descriptors** based on smooth and discrete Morse theory
  - Morse-Smale complexes, Reeb graphs, homology generators, barcodes, persistent diagrams, etc.

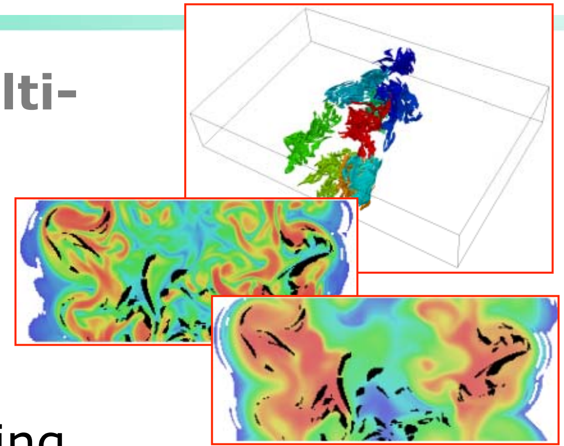


- **Homology-based shape recognition**
  - comparing persistent diagrams
  - computing optimal persistent homology generators
- **Topology-based visual analytics**
  - segmentations through Morse-Smale complexes
  - tracking level sets evolution through Reeb graphs



# Topological Data Analysis

## Challenges



- **Scalability** of existing approaches to **big, multi-dimensional** and **dynamic** data
  - new data structures and algorithms rooted in computation topology suitable for parallel or distributed implementation
- **Statistical topological data analysis**: learning using topological features
  - discriminative for learning models, agnostic and parameter-free
- Dealing with **multivariate data**: data equipped with multiple scalar functions
  - **multi-persistent homology** for shape recognition
  - visual analysis through **Pareto sets, Jacobi sets, Reeb spaces, critical clusters**