Geometry and Mesh Generation Template Approach for Facilitating Thermal and Fluid Analyses

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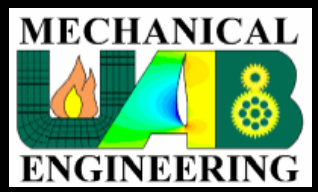
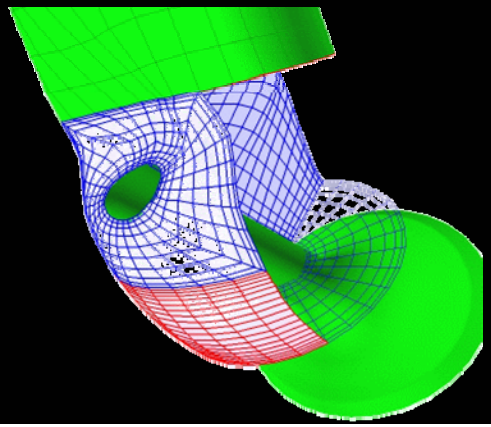
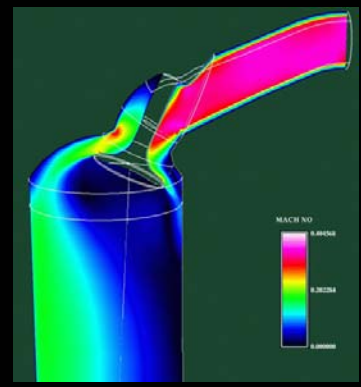
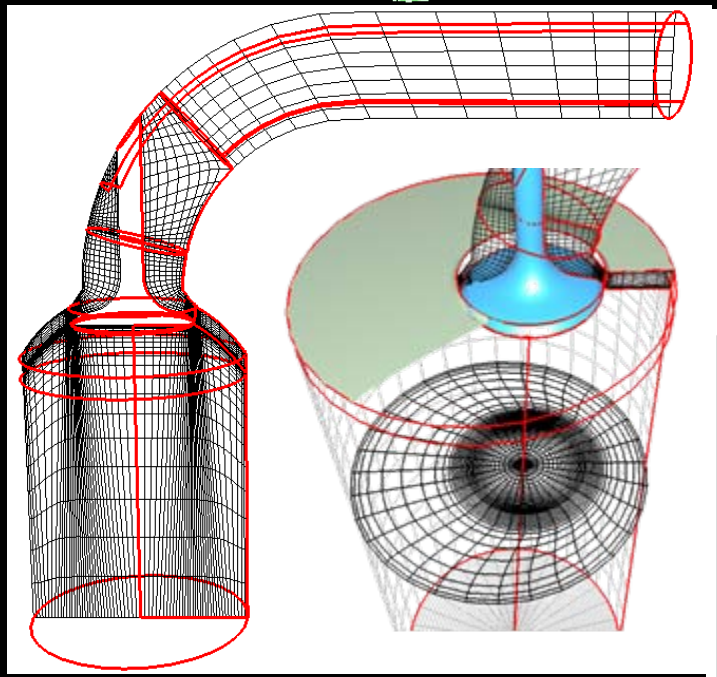


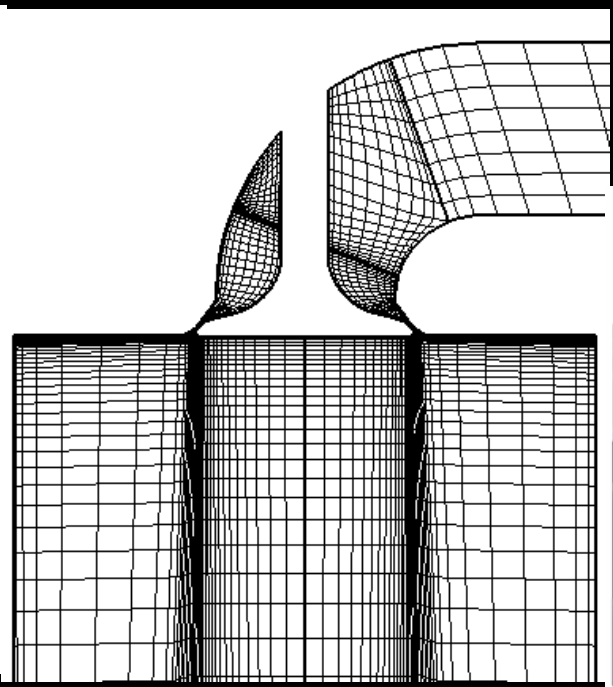
- Numerical Geometry and Mesh Generation
- Scientific Visualization and Virtual Environment
- Parallel Computing
- Software Framework
- Data Management/ Image Processing

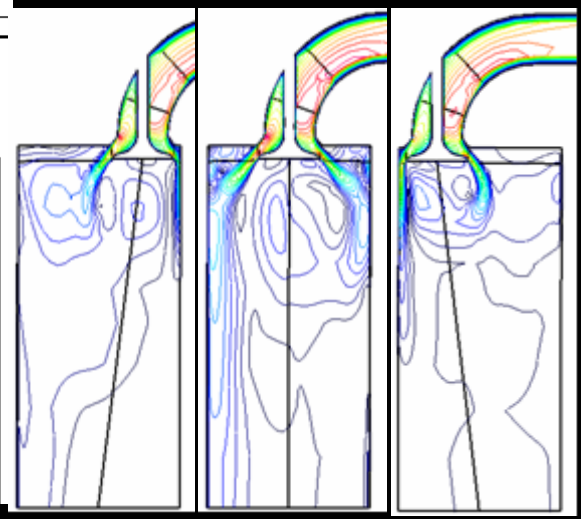
IC Engine Port Flow Simulation





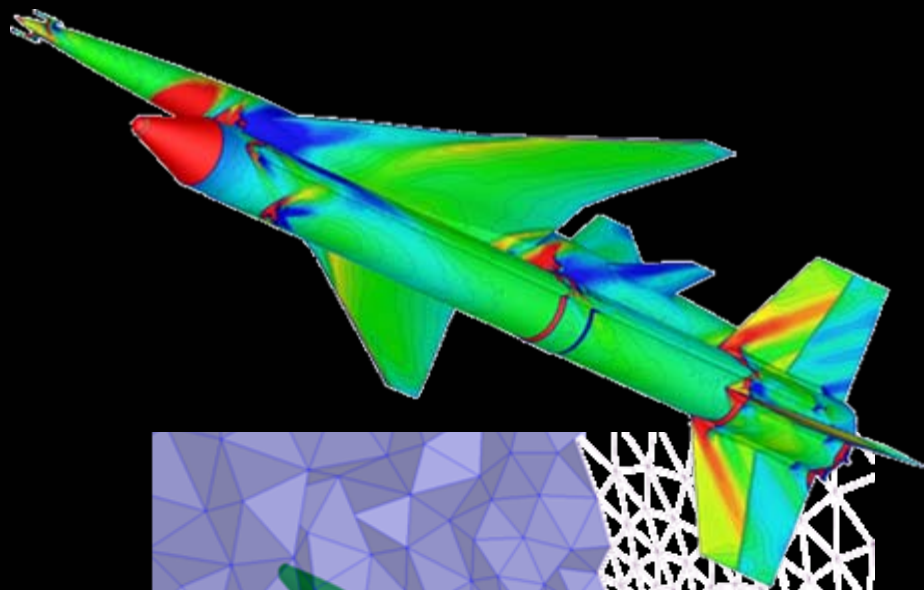


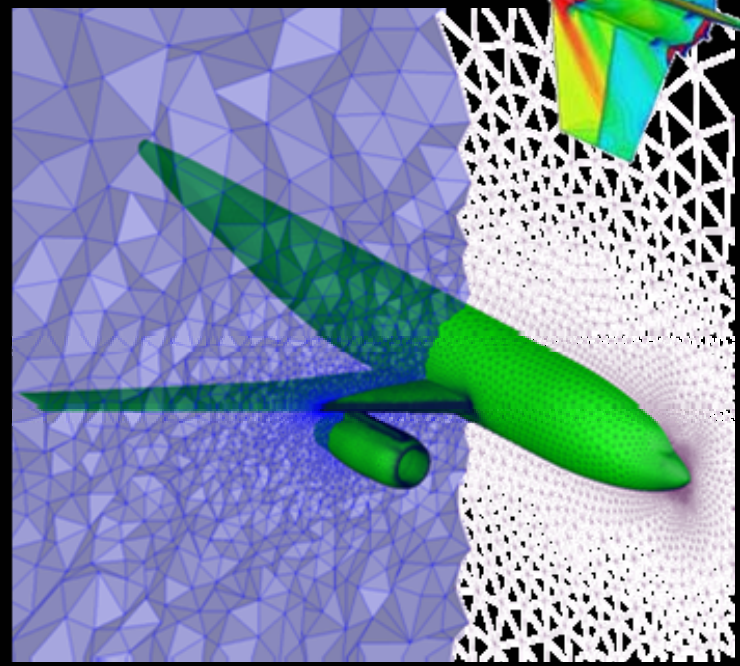




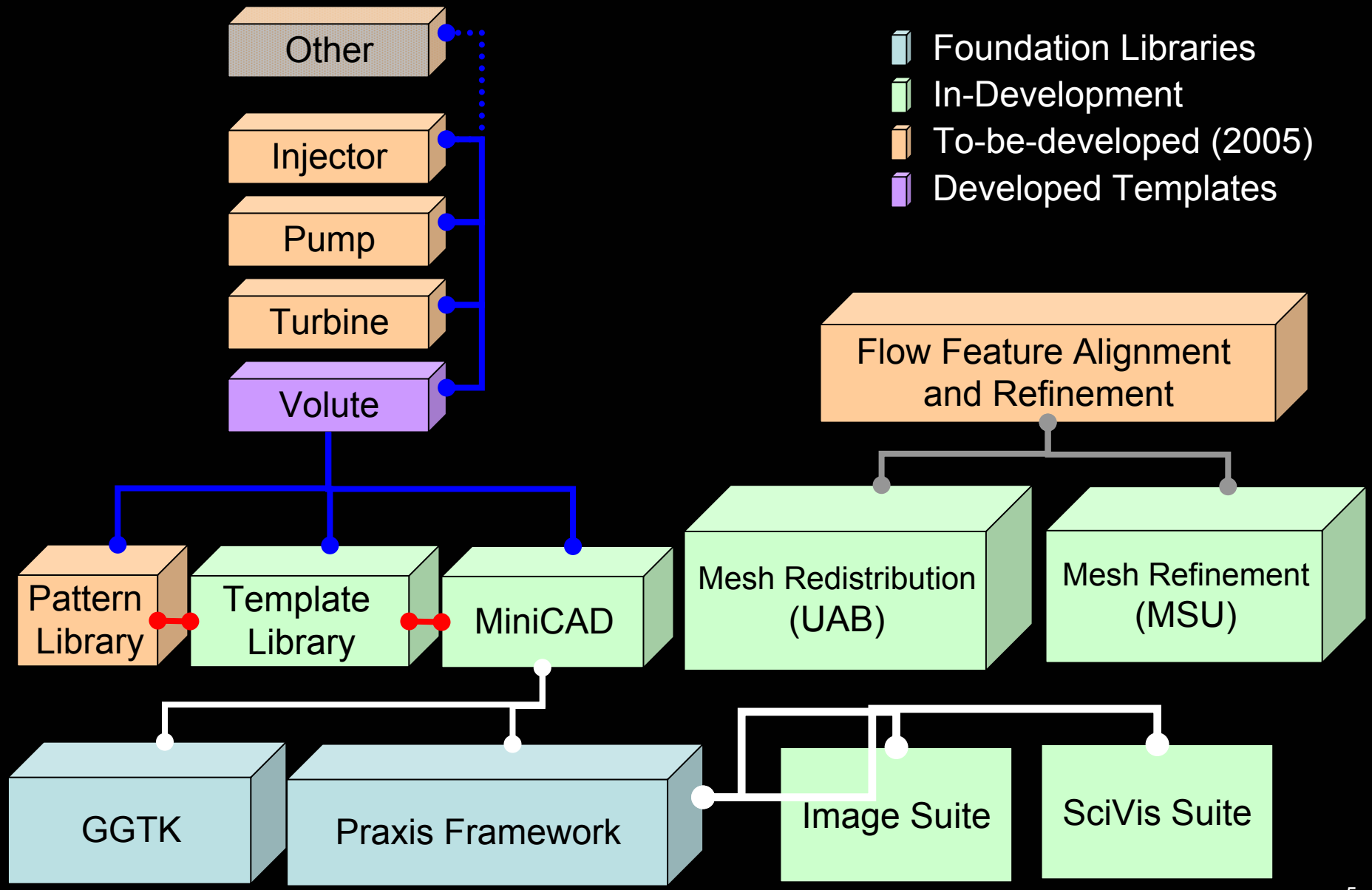
Outline

- ETLab Software Constellation
- Template Framework
  - Geometry
  - Mesh Generation
  - Pattern Library
  - Template Library
- Applications

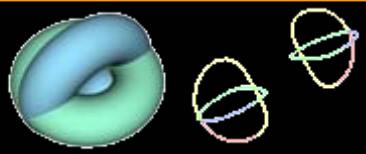




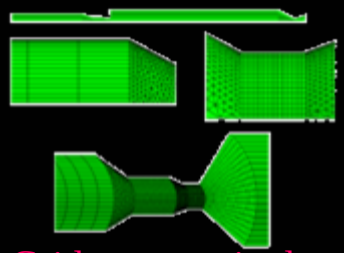
ETLab Software Constellation



Geometry and Grid Toolkit - GGTK



Surface-surface intersection



Grids over a single element injector

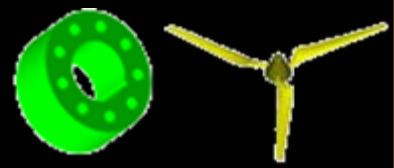
Crack insertion and growth

GGTK Library

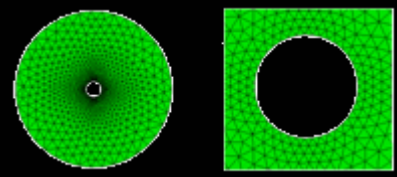
Geometric Modeling | Topological Representation | Grid Generation

Features

Unified tools for CAD and Grid
Watertight Geometry Representation
NURBS and Facetted Geometries
Surface-surface intersection
TFI and Elliptic Methods
Delaunay and Advancing Front Methods
IGES and STEP Readers
Parametric Modeling and Template Design



Parametric models: Hub and wind turbine

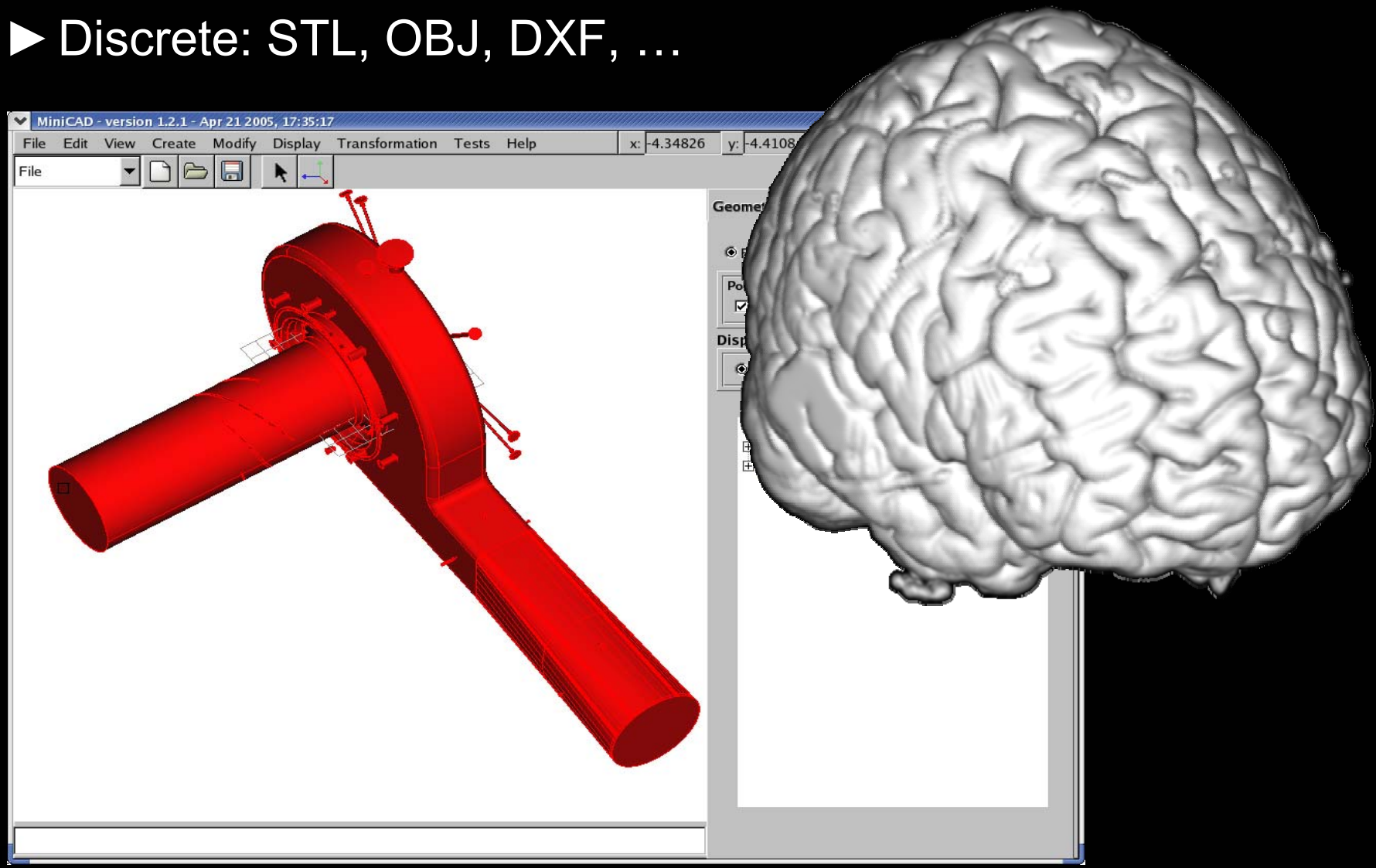


Unstructured grid by advancing front method

Volute blocks modeled in MiniCAD

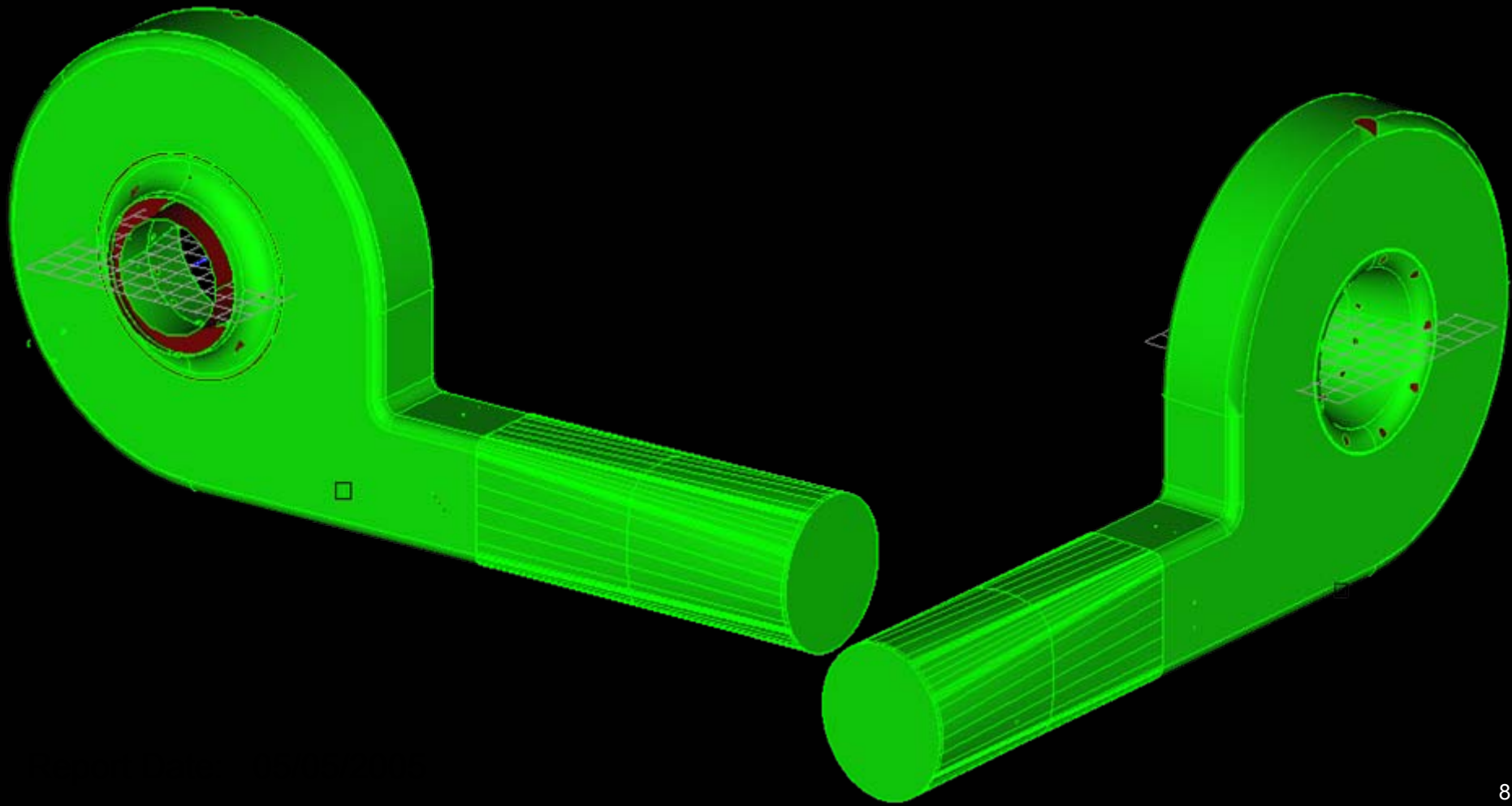
Parametric vs. Discrete Geometry

- Parametric: IGES, STEP, …
- Discrete: STL, OBJ, DXF, …

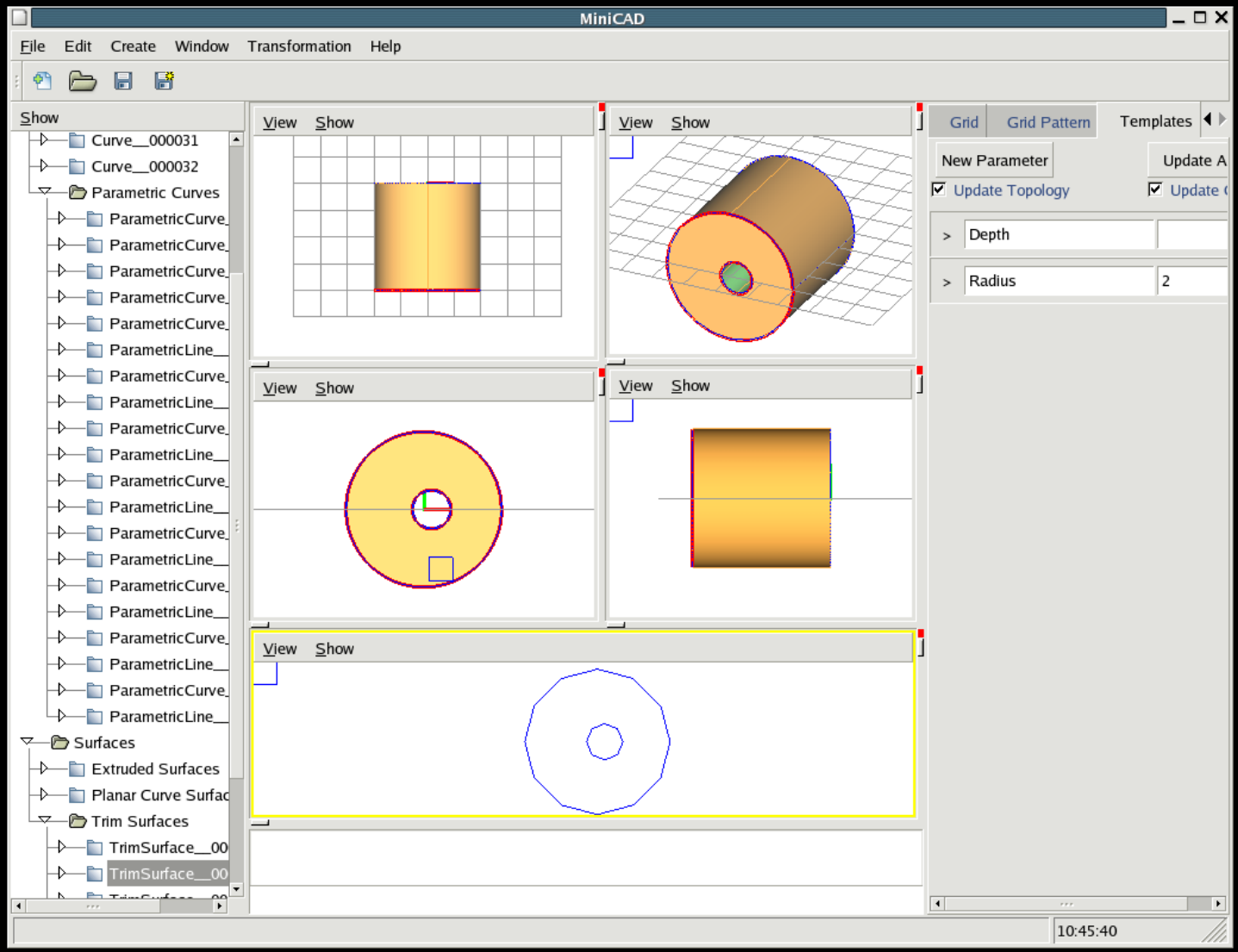


Parametric Geometry

- Geometry entities are *individually* well-defined analytically
- When put together, there may be gaps and other problems, though.

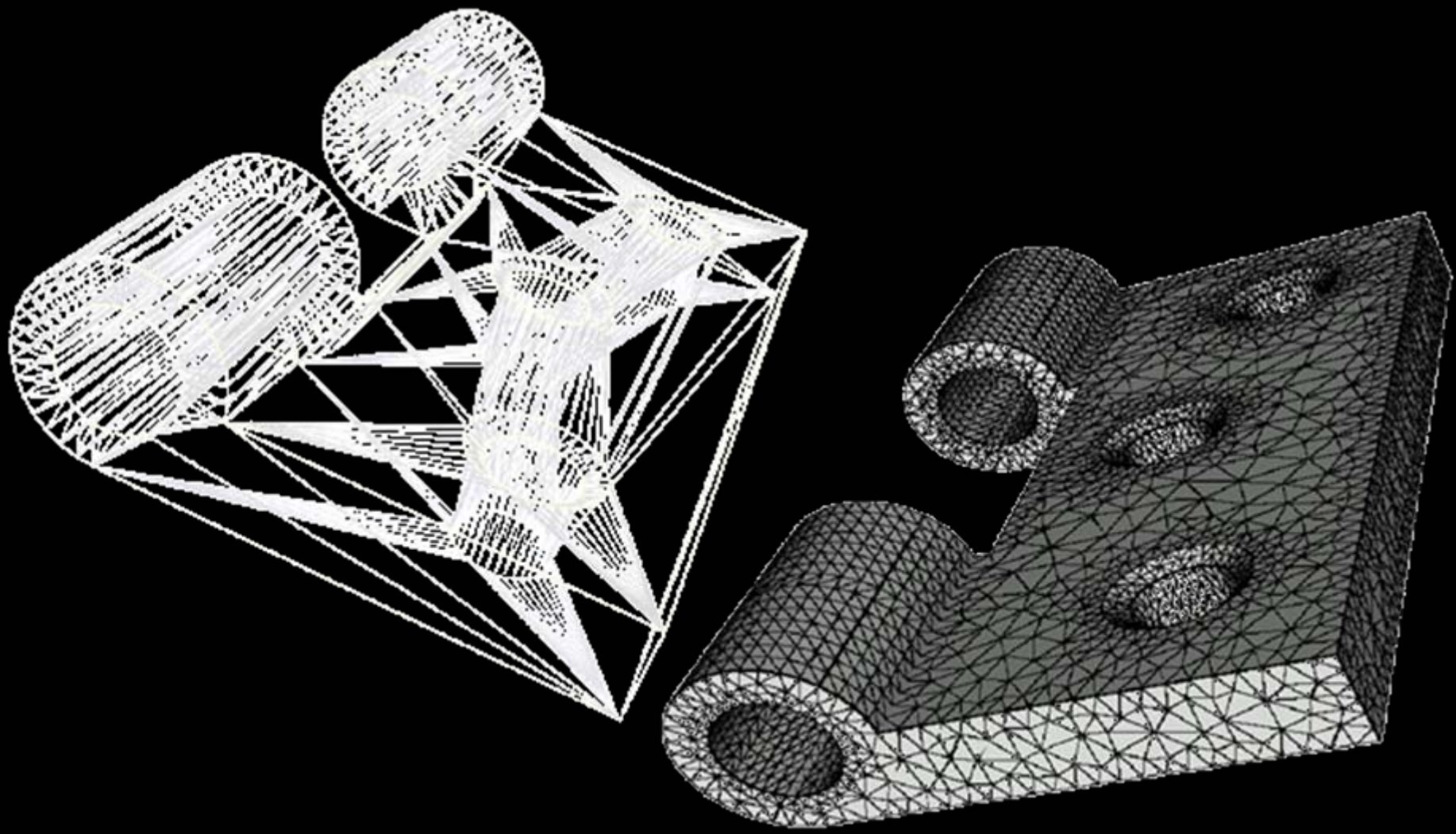


MiniCAD SYSTEM – GUI to GGTK



Discrete Geometry

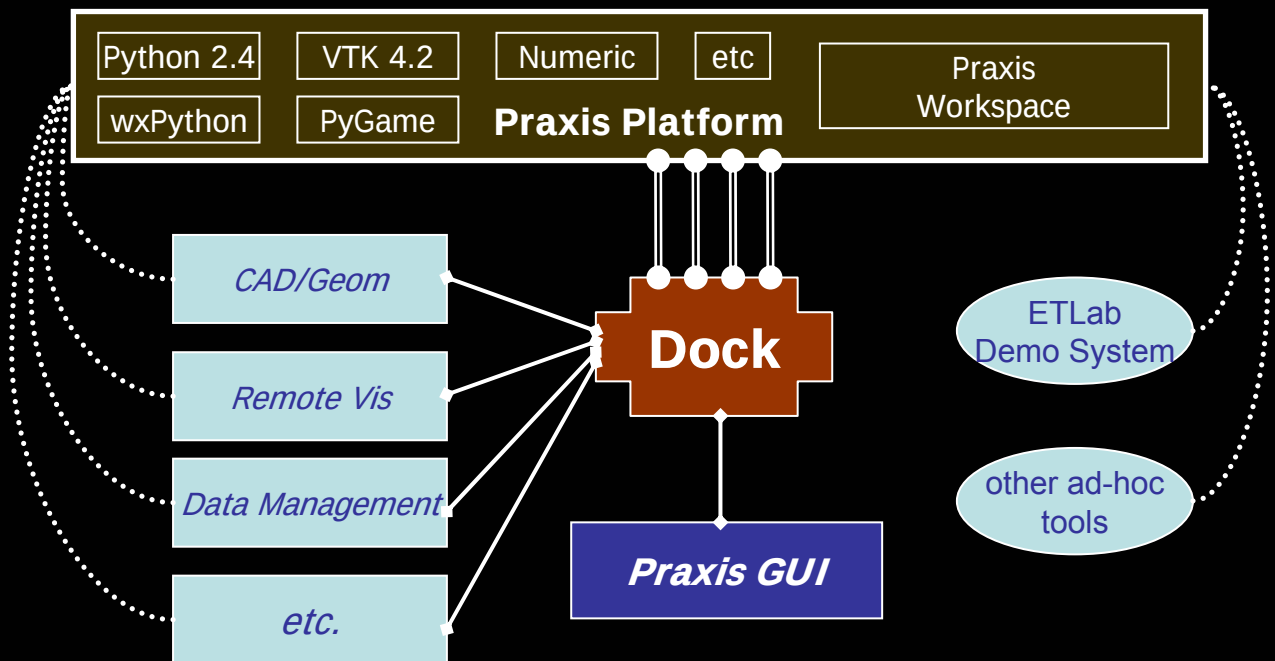
- Facetted or even with only point clouds



Praxis Environment

- Provide tools to simplify
  - cross-platform development
  - integration of existing codes
  - consistency of human interface
  - grid-like remote code interaction
- Design philosophy
  - Provide everything; require nothing.
  - Make simple things easy, and difficult things possible.

Dynamic GUI example



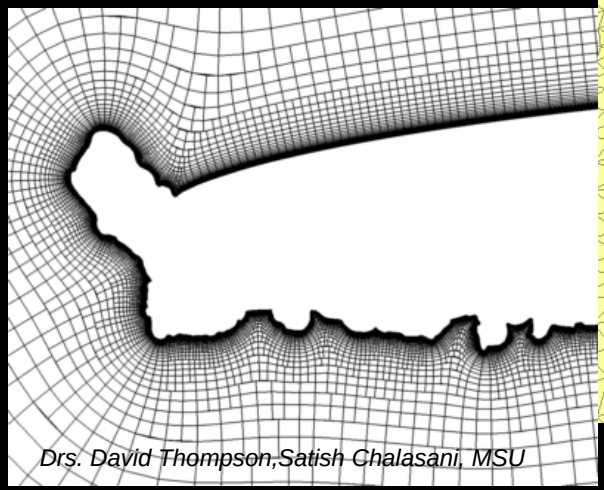
Praxis Environment

- **The Praxis Workspace**
  - provides a centralized set of high-level GUI tools within a structured framework to make human interface development simple and consistent.
  - The developer is not required to use these tools; they are there to help if needed and to provide a common base for module interoperation
- **The Praxis Dock**
  - provides a simple API for modules to discover the available resources and each other.
  - provides proxy modules to allow for the seamless integration of remote modules, accessed the same as local modules.

Mesh Types Supported

- Structured
- Unstructured
- Hybrid
- Generalized (MSU)

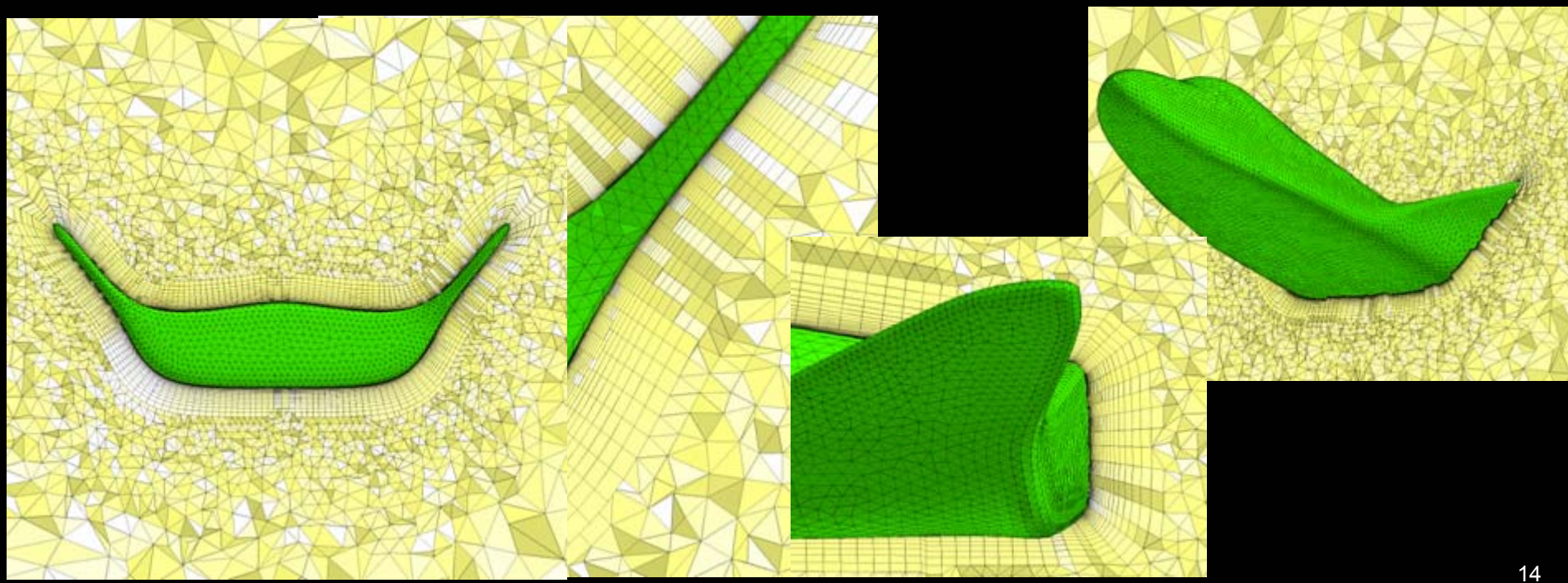
- Redistribution/ Refinement (MSU)



Drs. David Thompson,Satish Chalasani, MSU

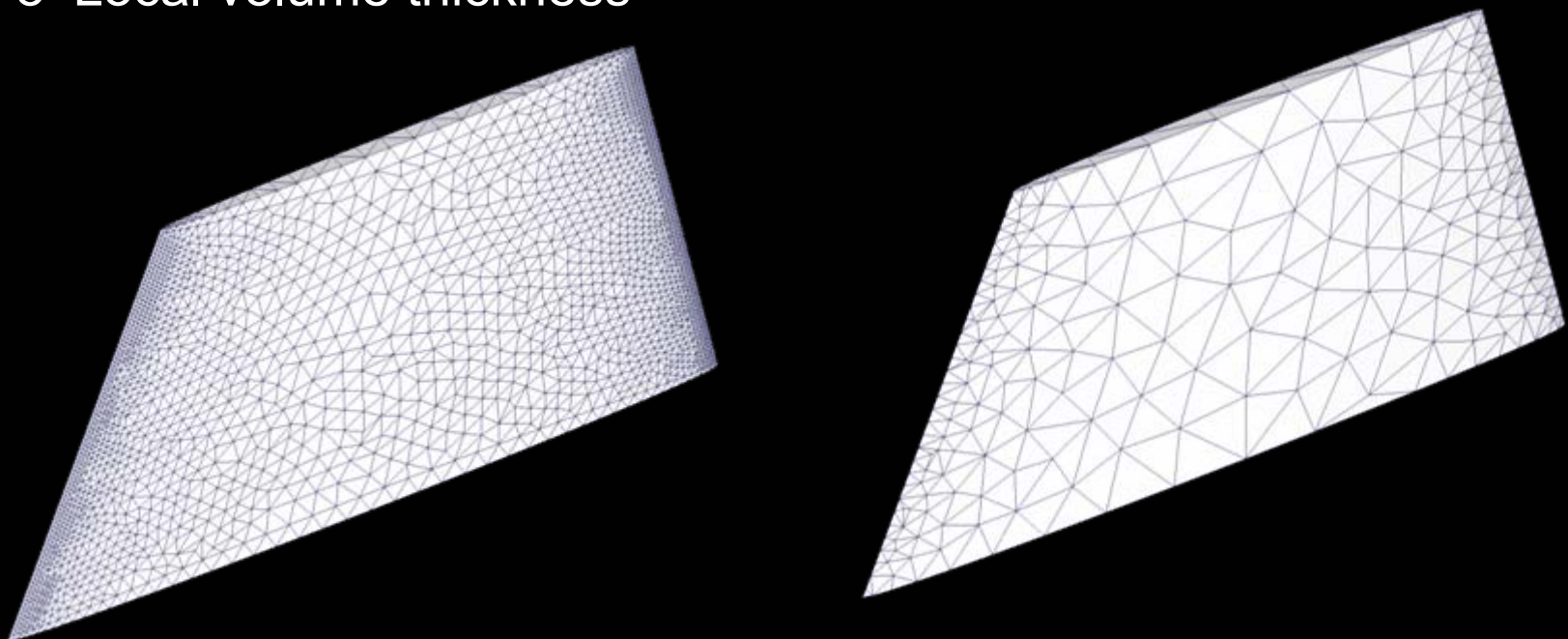
Hybrid Mesh Generation

- Technical Approach:
  - Prismatic layer generation by an advancing layer method
    - Starting from a surface mesh
    - Adding multiple normals at sharp corners
  - Tetrahedral meshing by an advancing front method
    - Face swapping based on the Delaunay property
    - Node smoothing by an angle-based smoothing method

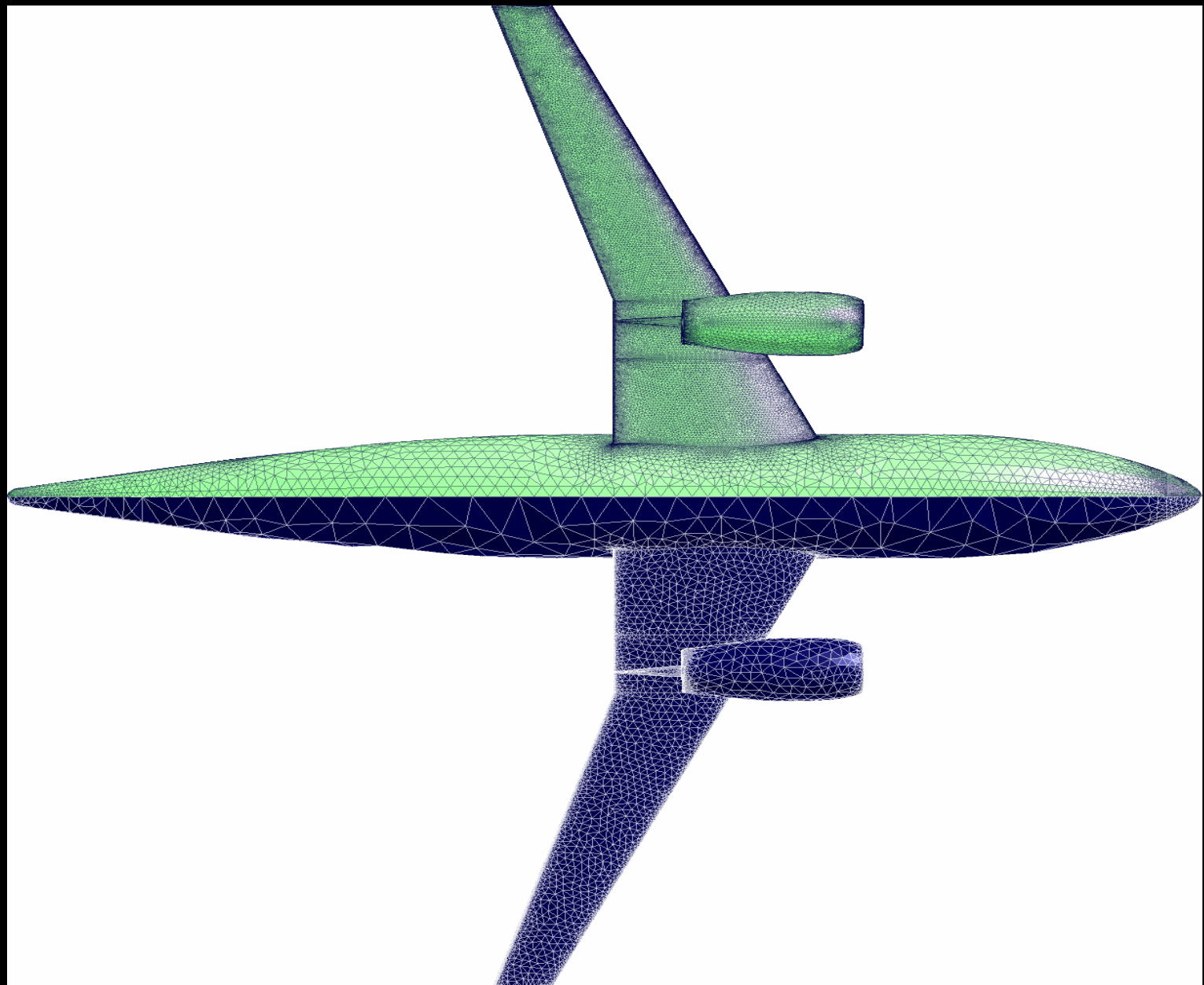


Surface Mesh Decimation

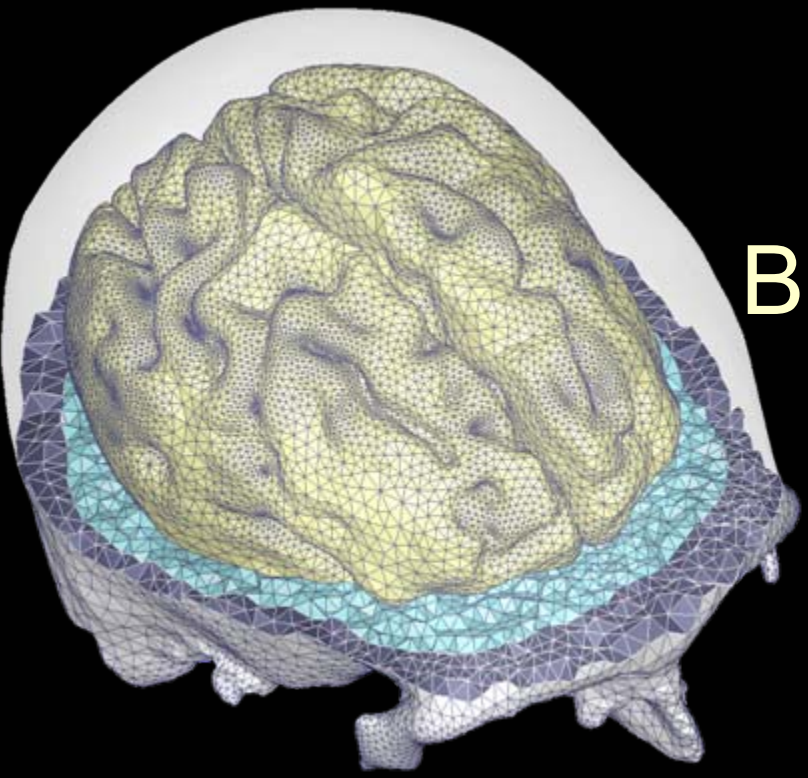
- Function-based mesh coarsening method (3D)
  - Miller, G. L. *et al*., "Optimal Coarsening of Unstructured Meshes," *J of Algorithms*, **31**: 29-65 1999 (in 2D)
- Spacing function at each node based on
  - Maximum length of the connected edges
  - Local surface curvature
    - Garimella, R. V. & Swartz, B. K., "Curvature Estimation for Unstructured Triangulations of Surfaces," LA-UR-03-8240, 2003.
  - Local volume thickness

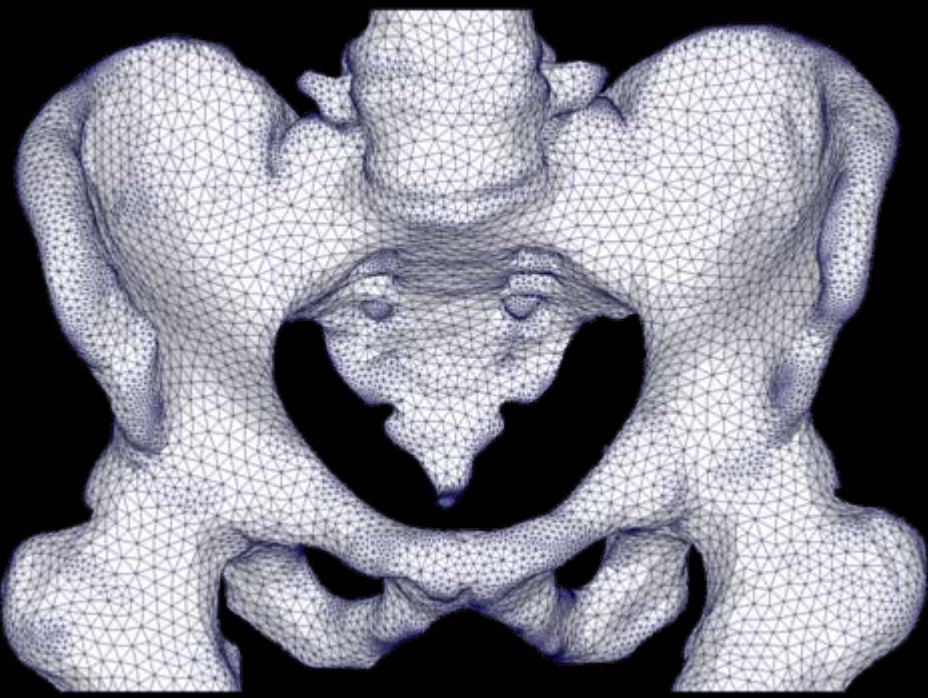


Surface Mesh Decimation

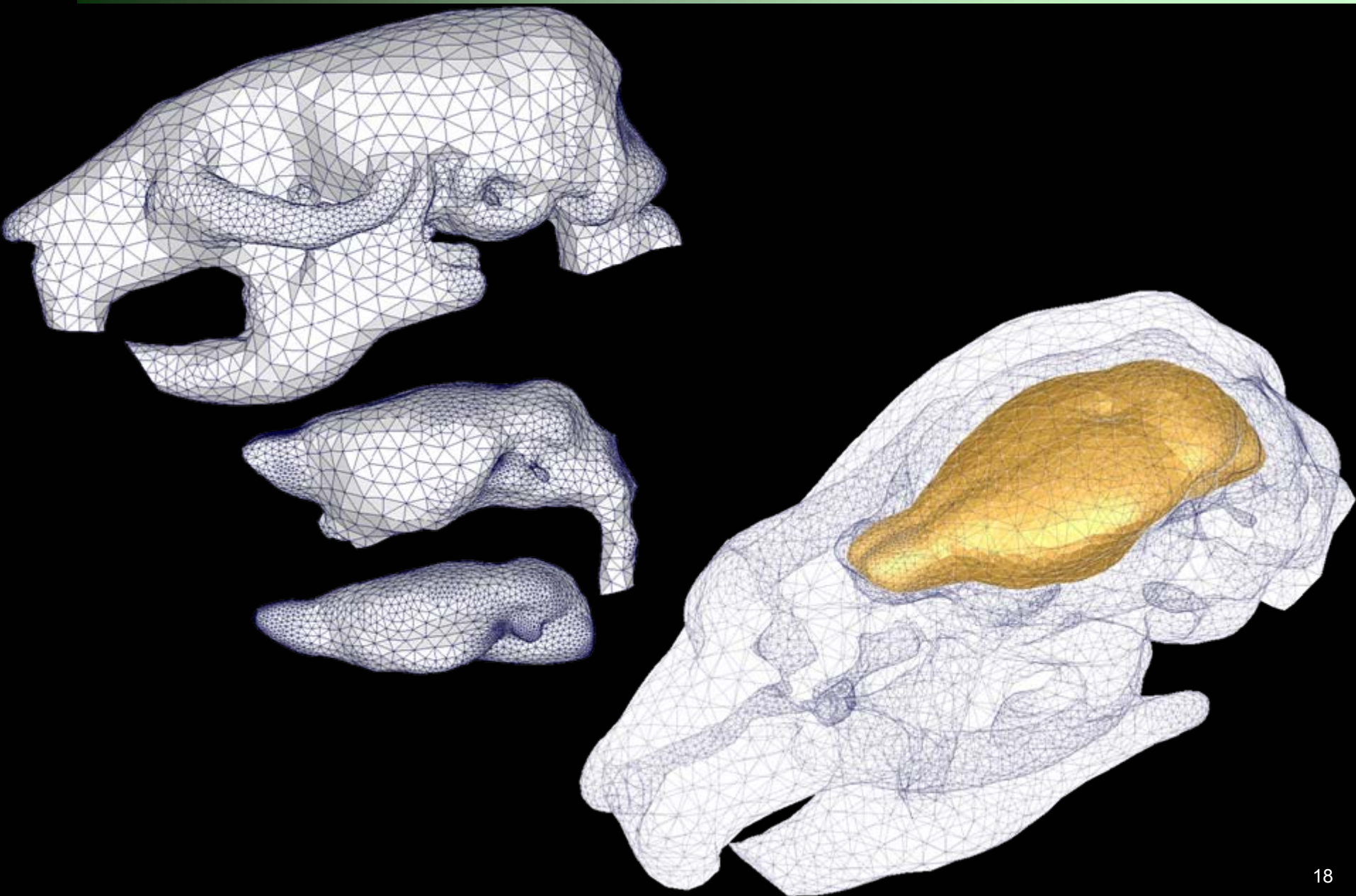


Biomedical Applications

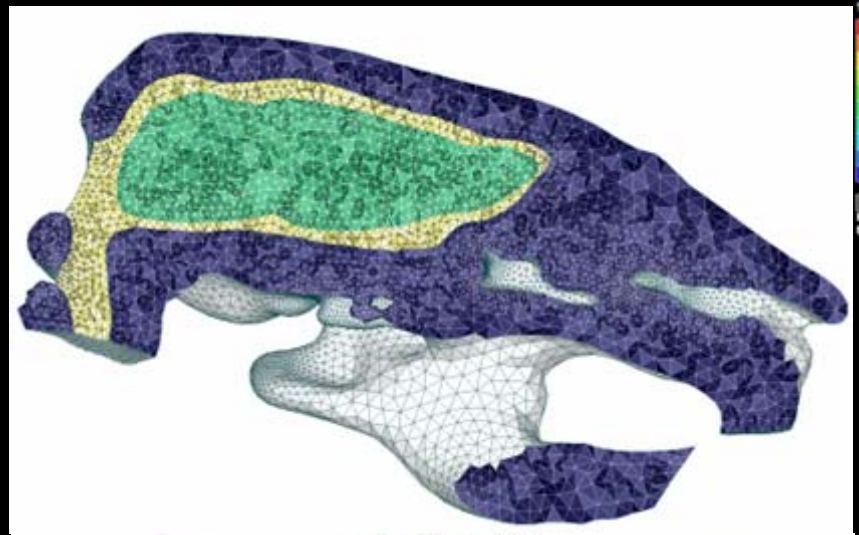


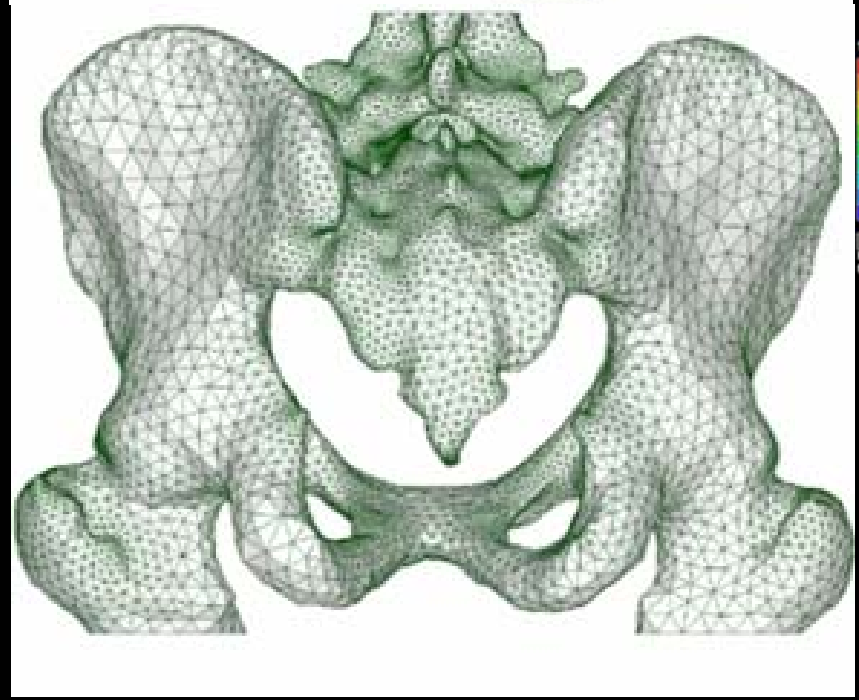


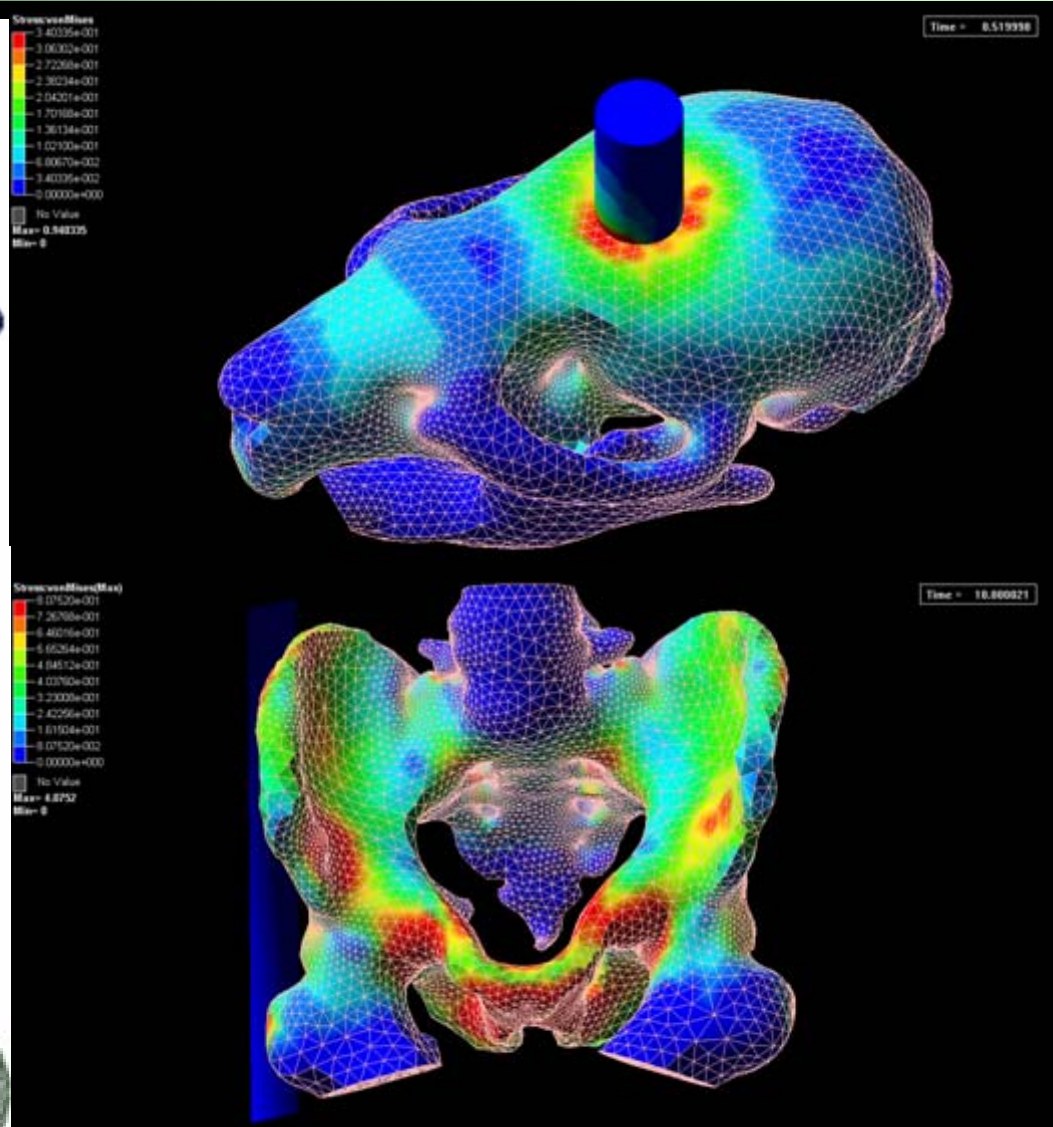
Impact Study



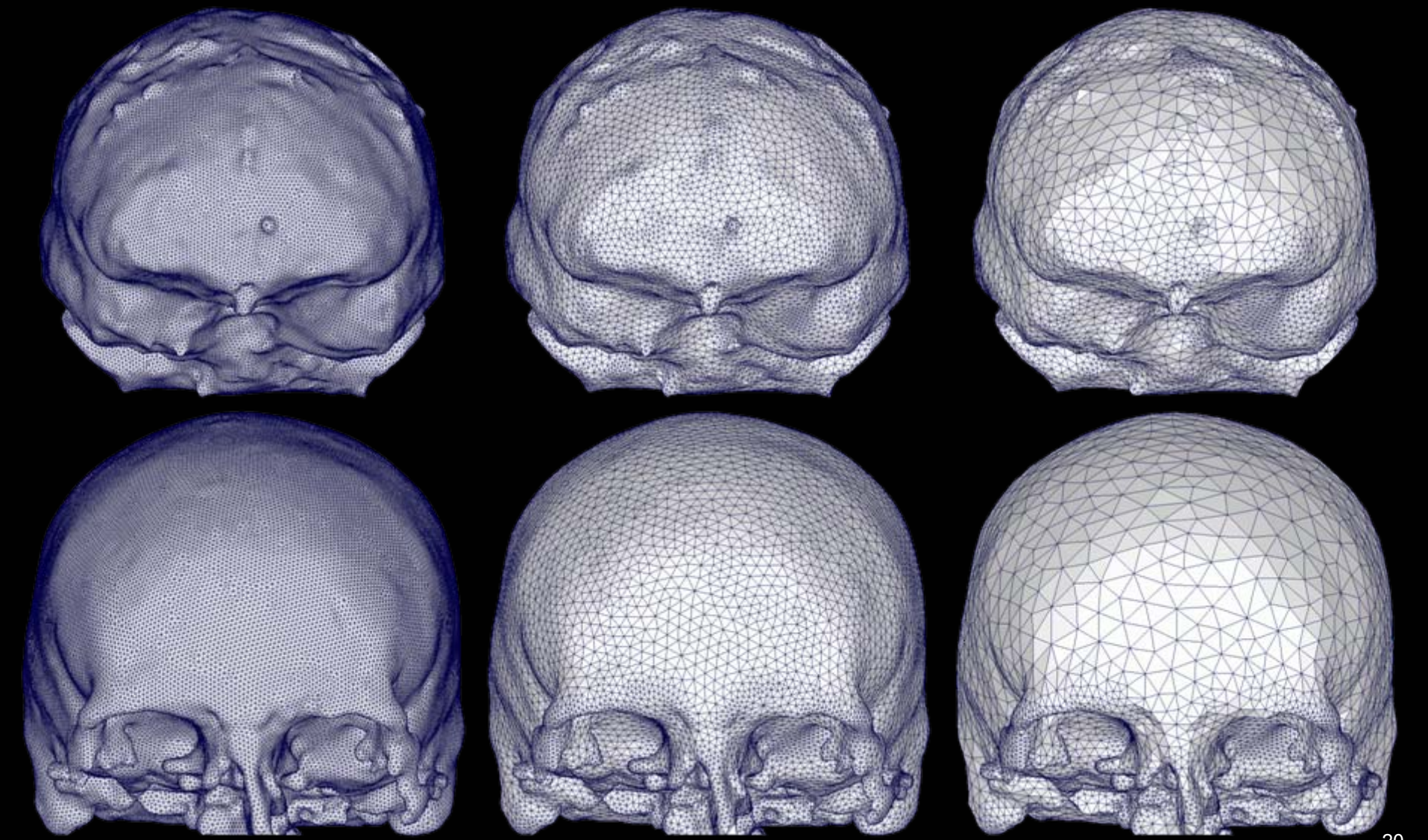
Biomedical Engineering Applications







Human Skull

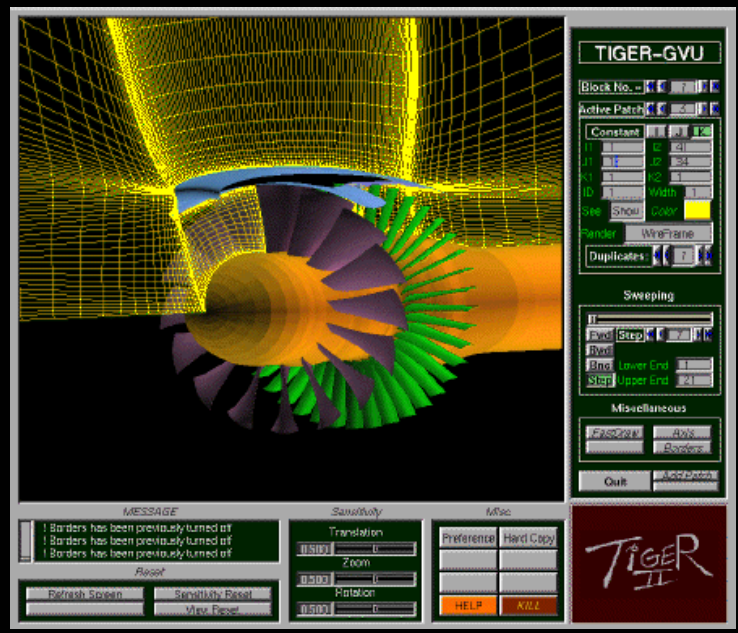


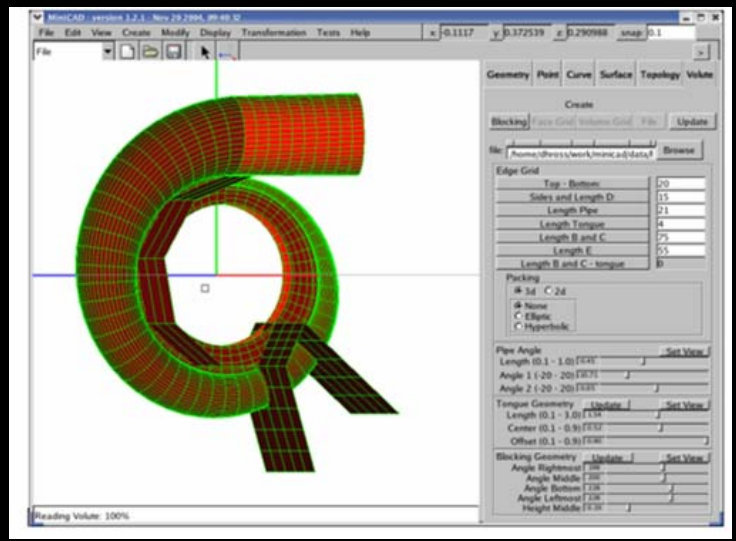
Interactive vs. Batch

- Batch
  - Generate meshes through pre-defined scripts without user interactions during the process
  - Fast and easy if the user knows what to change in the script file
  - Debugging can be frustrating
  - Eagle
- Interactive
  - Generate meshes through step-by-step user interactions (mostly GUI-driven with graphics)
  - Easy to know what we got through graphics,
  - User-friendly
  - But can be a laborious process
  - TIGER, Eagleview, GridGen, ICEM, etc.

Customized vs. Templates

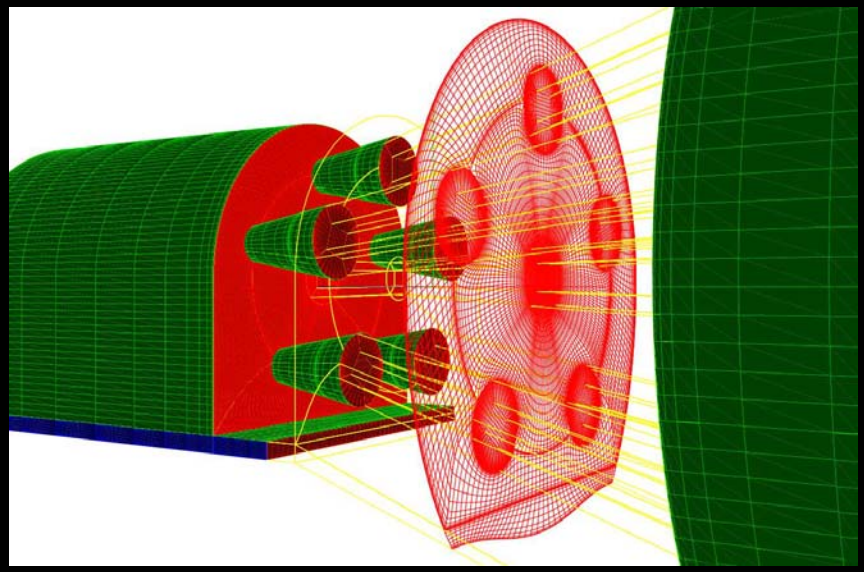
- Customized
  - Applicable geometry/ configuration is limited to a certain category
  - Many of the steps are automated
  - Maintain certain user interactions for modifications
  - TIGER
- Templates
  - Very specific configuration and geometry category
  - A lot of the steps are automated (batch)
  - Specific/ limited user control
  - Volute, SEI, MEI templates

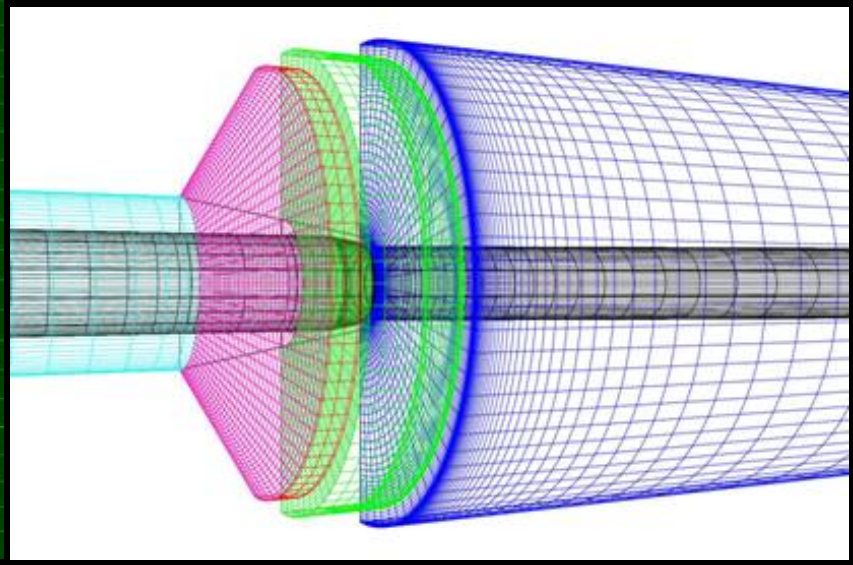




Template Framework

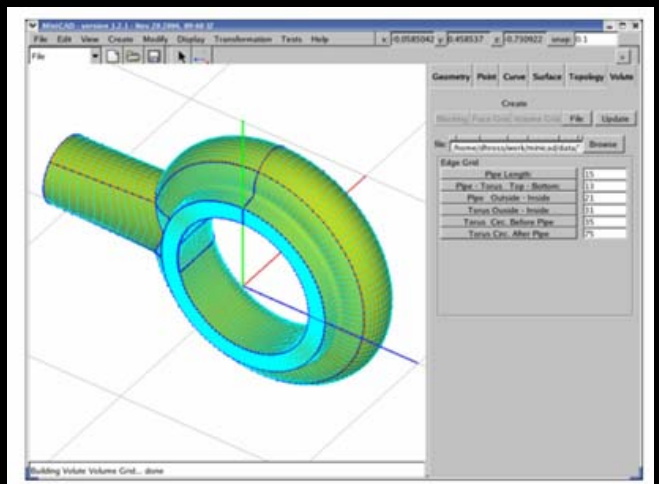
- Technical Approaches (Phase-I)
  - Batch mode
  - Difficult to use
  - Programmatic Coding
  - Tedious and time-consuming
  - Un-flexible to change geometry definitions and topology
  - Examples:
    - Single Element Injectors

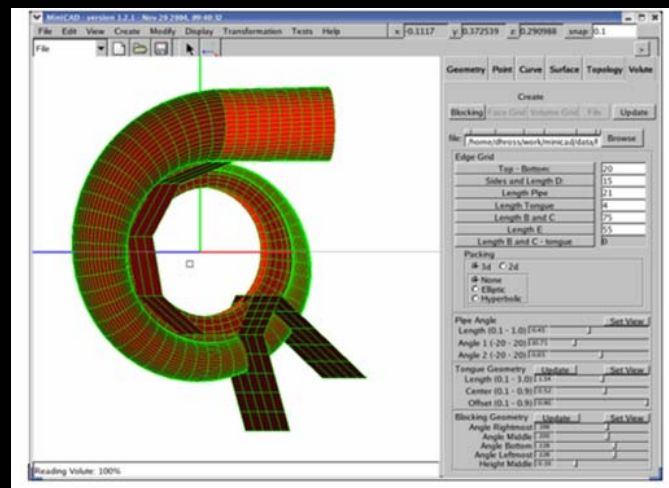




Template Framework

- Technical Approaches (Phase-II)
  - GUI-driven, graphically interactive
  - Easy to use
  - Programmatic Coding
  - Less tedious but time-consuming by accessing features in MiniCAD and GGTK
  - Un-flexible to change geometry definitions and topology
  - Examples:
    - Volute Templates (9 Configurations)
    - Torus Templates (3 Configurations)

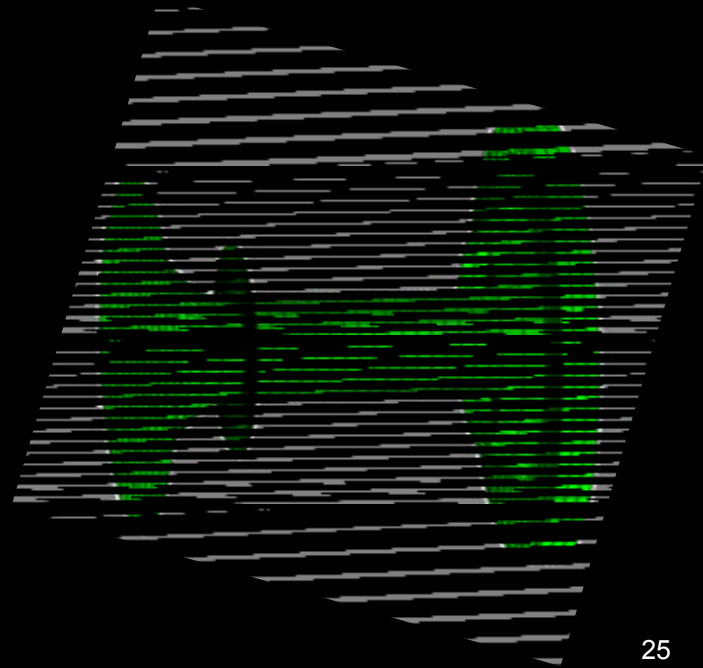




Template Framework

- Technical Approach (Phase-III, Current)
  - GUI –driven and graphically interactive
  - Easy to use
  - Dynamic User-defined GUI for geometry, topology and mesh
  - Automatic update on geometry, topology and mesh
  - XML specifications
  - Very easy to setup the template
  - Very flexible to change the geometry and topology

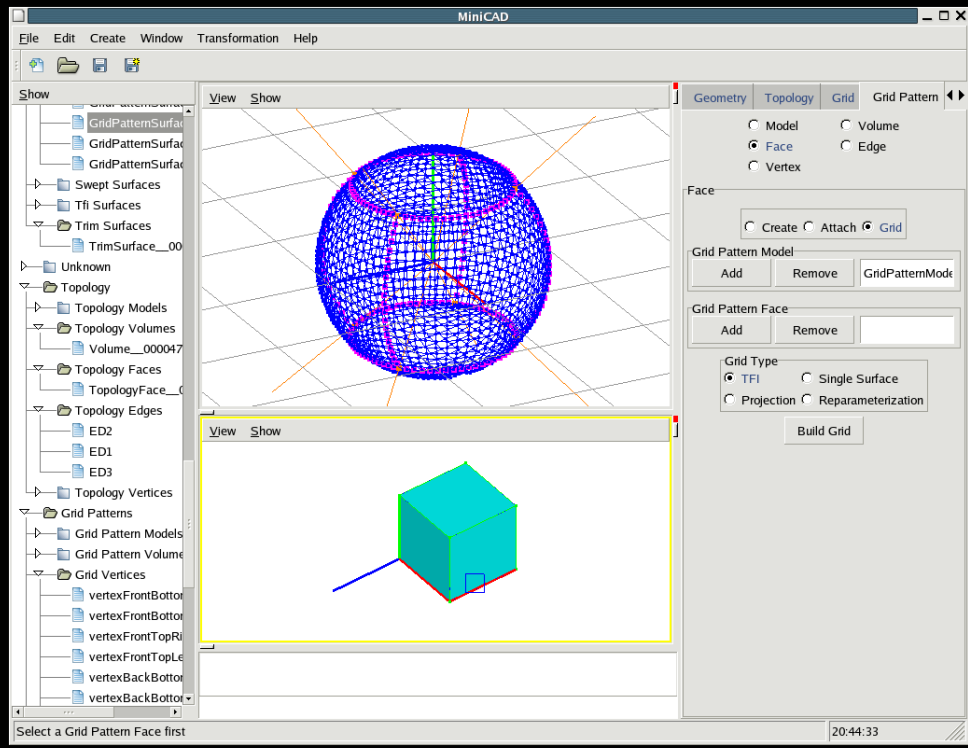
- Status Report (Demos)
  - Creating SEI geometry
  - Creating template
  - Creating SEI geometry by relational equations
  - Creating template by drag-and-drop
  - Creating SEI geometry volume

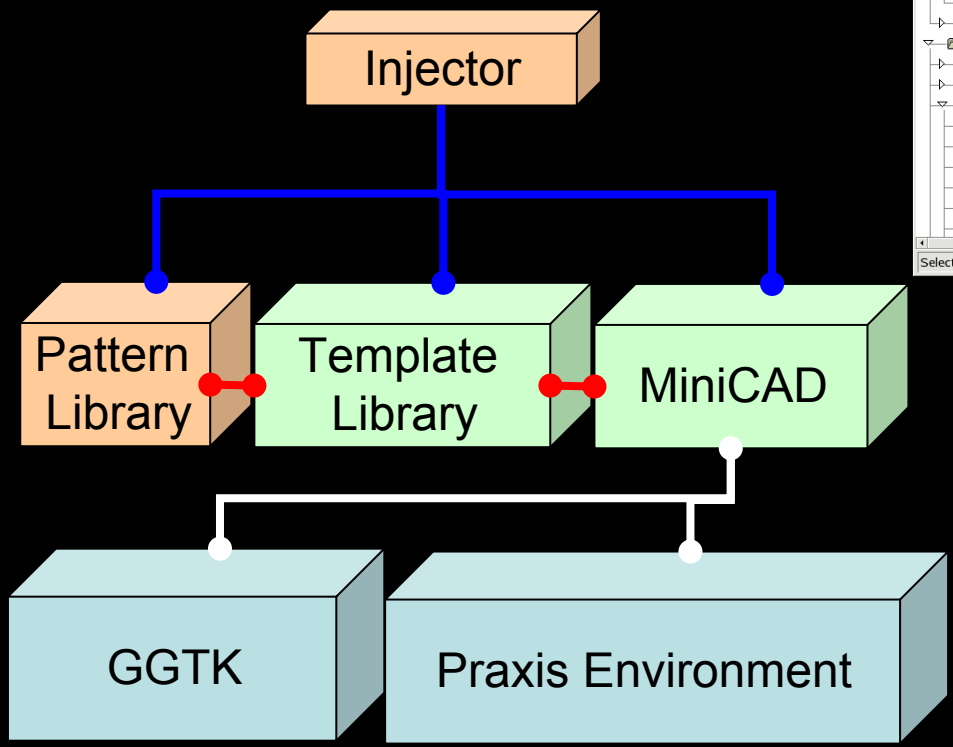


Components of the Framework

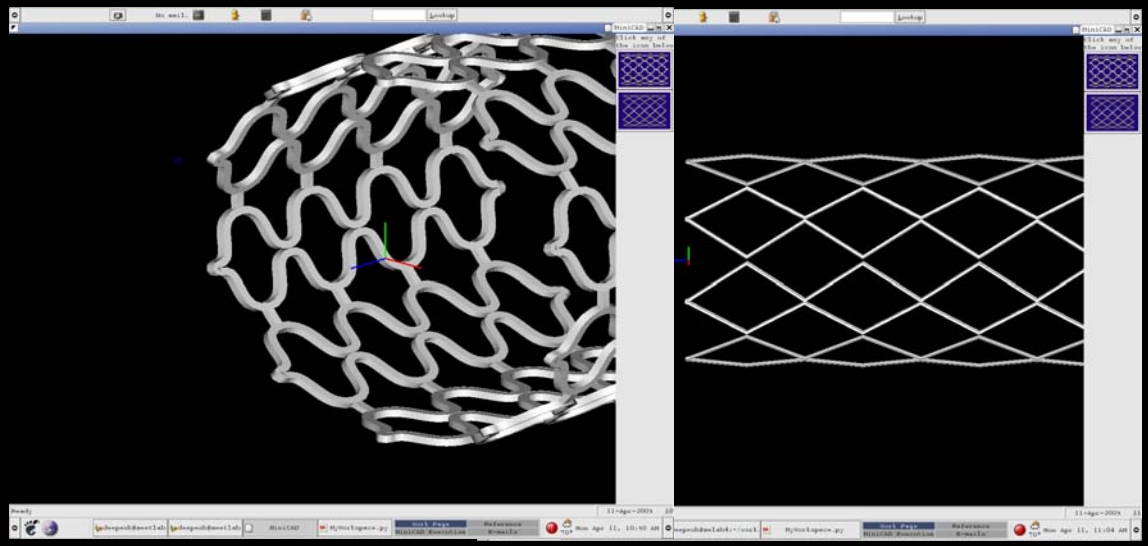
- GGTK
  - Supports many types of meshes
  - Supports CAD functionalities
- Praxis Environment
  - Supports GUI
  - Supports graphics
  - Supports inter-component communications
- Pattern Library
  - Allows quick mapping between geometry and sophisticated mesh patterns
  - Supports interactive pattern design
- Template Library
  - Collections of existing geometry/mesh generation templates
  - Volute, SEI, generic nozzle, generic aircraft, and other
  - Will continue to expand with more industrial/ NASA applications

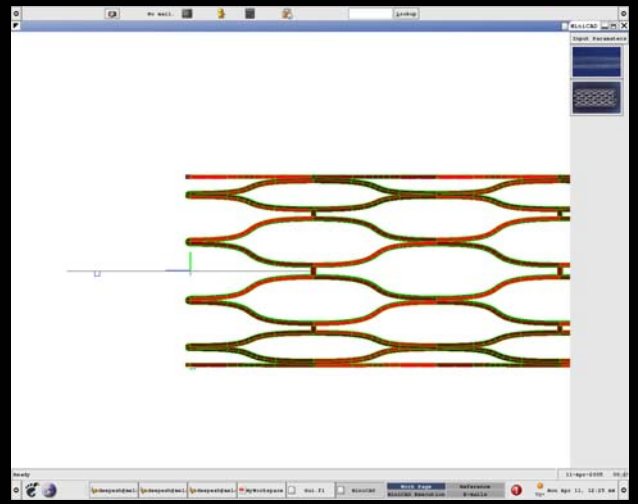
Template Framework

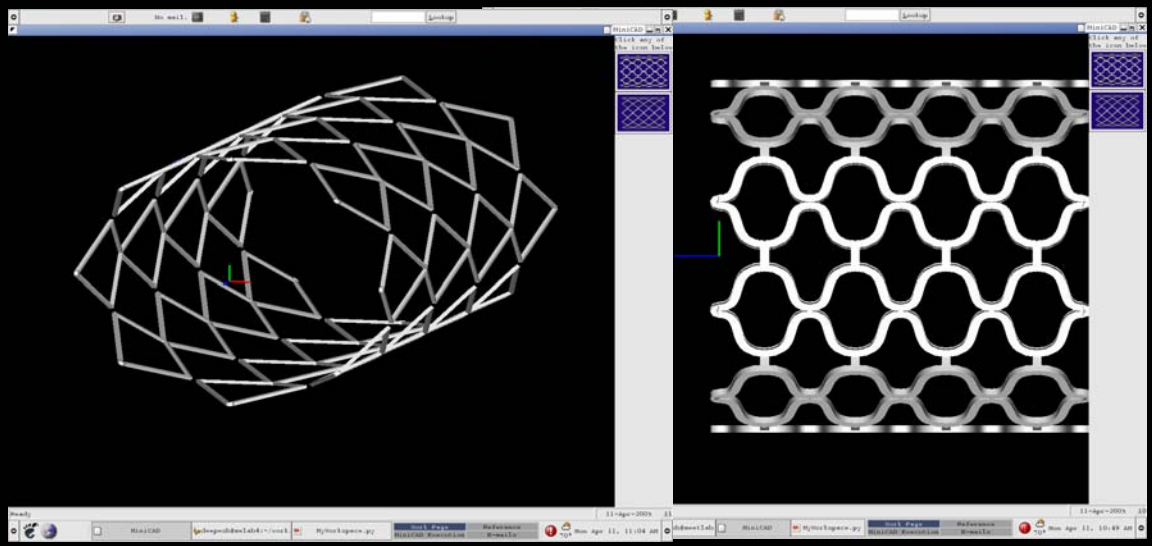




Examples: Stents



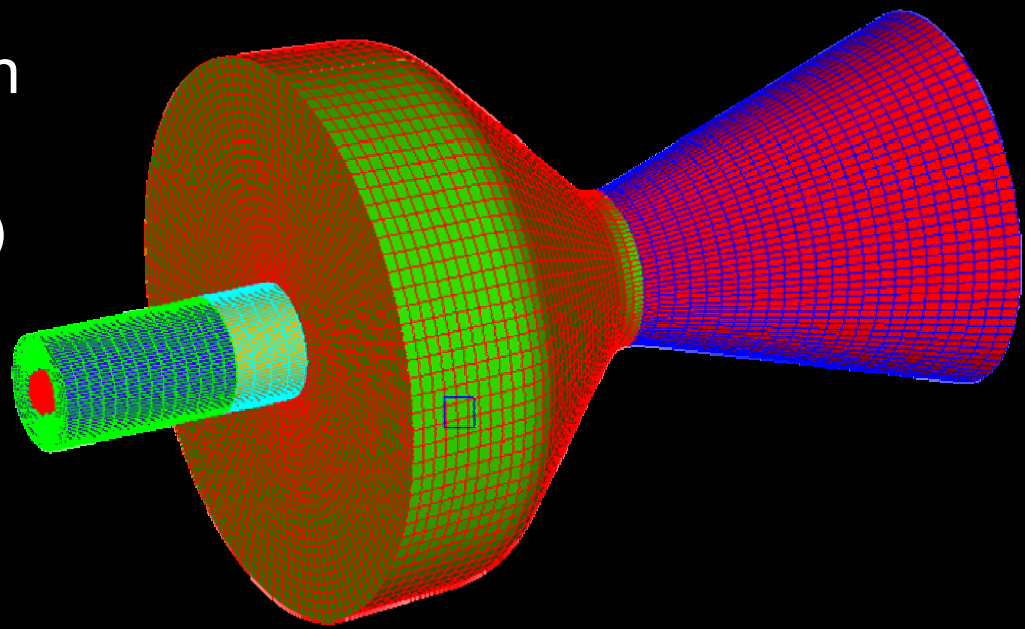




Demos

- SEI Geometry Creation
- SEI Template Creation
- Pattern Creation
- Pattern Application
- Unstructured Volute Template

- Additional Presentation
  - TUE Afternoon
  - UAB Booth (MON/TUE)



Acknowledgement

- ME UAB Members
  - Dr. S. Gopalsamy (GGTK)
  - Dr. Yasushi Ito (Unstructured, Hybrid and Parallel Mesh)
  - Mr. Corey Shum (Praxis, Medical Geometry, SciVis)
  - Mr. Doug Ross (MiniCAD, IGES)
  - Mr. Mark Dillavou (Praxis, MiniCAD, SciVis)
  - Mr. Dipesh Dimble (MS Student, Stent Template)
- Tohoku University (Japan)
  - Dr. Kazuhiro Nakahashi
- MSU
  - Dr. David Thompson
- Funding supported by
  - NASA CUIP Program
  - DoD PET Program
  - NSF ITR Program