

## THE UNIVERSITY of TENNESSEE KNOXVILLE

# Warp3D

**Description:** Open source code for 3D nonlinear analysis of solids primarily for fatigue and fracture simulations with static, impact, dynamic and thermal loadings

Purpose: Analyze material mechanics under stresses to improve designs with OpenMP Symmetric MultiProcessing (SMP)



### **HDF - Hierarchical Data Format**

**Description:** File Type .h5 **Parallelism:** Attributes are naturally separated

**Purpose:** Store data by efficient and compact means using a hierarchical format (similar to Unix)

### **Code:** Written in C, C++, Fortran

Team HDF5 Implementation -->







## **Rendering Software**

**GMESH:** CAD software that self-fabricates multidimensional meshes useful for FEA





**Dream3D:** Data analysis tool that creates voxel grain structures in a CAD modeled geometry



**Voxel2Tet:** Converts voxel representations to tetrahedral mesh with smooth interfaces





**Computational Mechanics:** HDF Parallel I/O Implementation In Warp3D Daniel Pledger (UTK), Carlos Estrada (NMSU), Rocco Febbo (UTK) Mentors: Tim Truster (UTK), Kwai Wong (UTK)

# **Project Overview**





### **<u>Goal</u>**: Use front end programs to add complexity for more accurate-to-life models and utilize HDF5 functions and format to store output from Warp3D after each computational step to be rendered by Paraview in parallel with OpenDIEL working with python GUI

### Milestones:

- Familiarize team with front and back end user interface
- Research program documentations and source codes
- Develop additional functions within source code
- Create complex mesh and surface elements in simulated objects
- Implement parallelism in I/O processing via HDF5 data storage format

## Front End

### **Measures Taken:**

- Setup and ran simulations using Warp3D
- Developed workflow to input GMSH mesh files into Dream3D to output voxel grain structures
- Created more realistic grain structures with tetrahedral meshes using Voxel2Tet
- Developed workflow to view models in Paraview • Wrote Matlab code that reads Voxel2Tet model files for simulation using
- Warp3D



## **Back End**



### **Measures Taken:**

- Developed new subroutine for parsing and processing user commands within a Warp3D input file
- Created interface between Fortran source code and team-written C functions
- Manipulated compilation process to successfully implement Fortran to C interface with HDF5 functions used in C function
- Wrote XDMF format descriptor file to accompany HDF5 file for Paraview to successfully render simulated object with Warp3D computed stress, strain, displacement, etc.

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example analysis of hollow sphere under internal pressure to illustrate extensive use of skew boundary conditions.
Internal radius: 10 in. External Radius: 60 in. Region Modeled: 0<= theta <=30 degrees 0<= phee <=30 degrees 3 elements over theta, 3 elements over phee, 5 elements over radius.
Nodal forces defined for 100 ksi internal pressure over initial internal surface. 100 ksi applied in step 1. An additional 400 ksi applied over 20 subsequent steps.
Large geometry change effects included but the nodal forces are not adjusted - the final pressure is thus less than 500 ksi due to increase in internal radius
Material is simply Mises with constant hardening.
The ability to define "local" coordinate systems at nodes for the specification of constraint is used here to model what is actually an axisymmetric problem.
Local coordinate systems are defined on the theta=30 and phee=30 faces. Displacements normal to these faces are zero in the axisymmetric model.

- Striving for processed simulations as accurate to "real" world physics as possible to include:
- Fracture analysis
- Crack propagation
- Object deformation
- Grain structure analysis



### **Motivation**:

- More effective nonlinear analysis
- Parallelism leading to quicker processing
- Higher definition of simulated models
- Accurate studies of material sciences
- Simple workflow for easy user interface



- data most precise to the physical world

- UTK and JICS.
- this project.



## Application



 Internal interactions and movements of grains Nodal connections (Element incidences)



## **Future Work**

• Persist in achieving more accurately simulated models for optimal

Continue developing parallelism in input and output processing

# Acknowledgements

• This research was supported with contributions made by NSF, ORNL,

• Mentors, Kwai Wong and Tim Truster, were crucial to the success of

• A special thanks to the developers of all open-source programs used.