GENIE++ – A Multi-Block Structured Grid System

by

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ABSTRACT

The computer code GENIE++ (Soni et al. 1992) is a continuously evolving grid system containing a multitude of proven geometry/grid techniques. The generation process in GENIE++ is based on an earlier version. The process uses several techniques either separately or in combination to quickly and economically generate sculptured geometry descriptions and grids for arbitrary geometries. The computational mesh is formed by using an appropriate algebraic method. Grid clustering is accomplished with either exponential or hyperbolic tangent routines which allow the user to specify a desired point distribution. Grid smoothing can be accomplished by using an elliptic solver with proper forcing functions. B-spline and Non-Uniform Rational B-splines (NURBS) algorithms are used for surface definition and redistribution. The built-in sculptured geometry definition with desired distribution of points, automatic Bezier curve/surface generation for interior boundaries/surfaces, and surface re-distribution is based on NURBS. Weighted Lagrange/Hermite transfinite interpolation methods, interactive geometry/grid manipulation modules, and on-line graphical visualization of the generation process are salient features of this system, which result in a significant time savings for a given geometry/grid application.

The development of the system, as well as computational examples of practical interest will be presented to demonstrate the success of these methodologies. Complete documentation is available using Mosaic. Versions are available for PC's, X window, and SGI systems. It is planned to place this code in the public domain by August 1995.
GENIE++: A Structured Multi-Block Grid System

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ENGINEERING RESEARCH CENTER
COMPUTATIONAL FIELD SIMULATION
COMPLEX GEOMETRY / COMPLEX PHYSICS
Grid Strategies

Unstructured

Structured

- Advancing Front
- Delaunay
- PDES
- Other

- Algebraic
- PDES
- Other
GRID INFLUENCE

- All Positive or All Negative Volumes
- Orthogonality (Not Too Skewed)
- Smooth
- Aspect Ratio

- Accuracy
- Truncation Errors
- Stability
- Treatment of BCS
- Economy ($)
GENERATION STEPS

8  Refined Grid

1  Algebraic Grid

1  Surface Grids and Patches

70  Geometry Definition

5  Distribution of Points

15  Mapping

Physical Space  Computational Space
STRETCHING FUNCTIONS

★ Exponential $\rightarrow f(x) = \frac{e^x - 1}{e - 1}$

★ Hyperbolic Tangent $\rightarrow f(x) = 1 + \frac{\tanh(\alpha(x-1))}{\tanh\alpha}$

★ Hyperbolic Sine $\rightarrow f(x) = 1 - \frac{\sinh(\alpha(1-x))}{\sinh\alpha}$
STRETCHING OPTIONS

Exponential

Hyperbolic Tangent

Evenly spaced

Packed toward the low-index end

Packed toward the high-index end

Packed toward both ends

Packed toward an interior point

Options for Distributing Points
A BOUNDARY CURVE, SURFACE, OR VOLUME

\[ G(11 \rightarrow 12, \rightarrow J1 \rightarrow J2, K1 \rightarrow K2) \]

Curve \[ G(11 \rightarrow 12, J \rightarrow J, \bar{K} \rightarrow \bar{K}) \]

A Surface \[ G(11 \rightarrow 12, J1 \rightarrow J2, \bar{K} \rightarrow \bar{K}) \]

A Volume \[ G(11 \rightarrow 12, J1 \rightarrow J2, K1 \rightarrow K2) \]
GENIE
Grid Generation Process / Geometry Definition

Volume
Physical Configuration

Sub-Volumes

Contiguous Blocks

Surfaces

Surfaces Patches

Boundary Segments
GEOMETRY GENERATION

• Semi-Interactive Construction

• Analytic:
  Points, Line, Circle, Ellipse, Super-Ellipse,
  Polynomial, Plane, Ruled Surface, Ellipsoid,
  Hyperboloid, Paraboloid, NASA Airfoils, . . .

• Sculptured:
  Spline-Akima, B-Spline, Rational B-Spline,
  Polynomial-Hermite, LaGrange, Bezier,
  Coon's Patch, NURBS, . . .
GEOMETRY MANIPULATION

- Body of Revolution
- Ruling, Marching, TFI, Coon’s Patch
- Transformations: Translation, Rotation, Scaling, Mirror Image
- Cut. Paste, Blend, . . .
- Intersections and Projections
ALGEBRAIC

- Fast
- Precise Spacing Control
- Interactive User Interface
- Possible Overlapping
- Requires High Degree of Understanding
- Generalization!
- Propagation of Slope Discontinuities

PDES

- Inherent Smoothness
- Resistant To Grid Line Overlapping
- No Propagation of Slope Discontinuities
- Competitive Enhancement of Smoothness, Orthogonality and Concentration
- Readily Adaptable for Generalization
- Distribution Loss
APPRAOCH

Objective: Accomplish orthogonality – smoothness without any distribution loss.

- Work hard with Algebraic
  - Precise Spacing Control (Grid Spacings, Areas, Volume)
  - Inexpensive and Fast
  - Interior Bezier Curve/Surface Specification for Sub-blocks
  - Weighted Transfinite Lagrange and Hermite Interpolation
  - Precise Spacing Control (Grid Spacings, Areas, Volume)

- Use elliptic for a quick fix
  - Smart Forcing Functions
  - 3-5 Iterations (maximum)
WEIGHTED TRANSFINITE INTERPOLATION

Physical Space

\((x_{ij}, y_{ij})\)

Distribution Space

\((s_{ij}, t_{ij})\)

Computational Space

\((i, j)\)

50 x 40
GENERAL ELLIPTIC GENERATION SYSTEM

$$\sum_{i=1}^{3} \sum_{j=1}^{3} g^{ij} r_{\xi^i \xi^j} + \sum_{k=1}^{3} \phi_k r_{\xi^k} = 0$$

$$g^{il} = \frac{1}{g} (g_{jmgkn} - g_{jnkn}) \quad i = 1, 2, 3; j = 1, 2, 3; (i, j, k) \text{ and } (l, m, n) \text{ cyclic}$$
EVALUATION OF FORCING FUNCTIONS

\[
\sum_{i-1}^{3} \sum_{j-1}^{3} \sum_{k=1}^{3} \left( g_{ij} \frac{(g_{ij})_{k}^{k} - (g_{ij})_{q}^{q}}{2} \right) = 0
\]

\[
q = 1, 2, 3
\]

\[
\sum_{i} \sum_{j} \sum_{k} \frac{(g_{ij})_{k}^{k} - (g_{ij})_{q}^{q}}{2} = 0
\]

\[
\theta \cdot \sum_{i} \sum_{j} \sum_{k} (g_{ij})_{k}^{k} - (g_{ij})_{q}^{q} = 0
\]

\[
\sum_{i} \sum_{j} \sum_{k} (g_{ij})_{k}^{k} - (g_{ij})_{q}^{q} = 0
\]

\[
\sum_{i} \sum_{j} \sum_{k} (g_{ij})_{k}^{k} - (g_{ij})_{q}^{q} = 0
\]

\[
\sum_{i} \sum_{j} \sum_{k} (g_{ij})_{k}^{k} - (g_{ij})_{q}^{q} = 0
\]

\[
\sum_{i} \sum_{j} \sum_{k} (g_{ij})_{k}^{k} - (g_{ij})_{q}^{q} = 0
\]
GENIE Family of Grid Generation Codes

GENIE User's Manual
Version 1.0

Dr. Joseph Benson
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Engineering Research Center for Computational Fluid Simulation
GENIE++
Characteristics
GENIE++

Geometry Mode

Computational Mode

- Sculptured Curves and Surfaces
- One Block at a Time With One Extra Block in On-Line Memory
INITIALIZATION OPTIONS
1 TOGGLE REAL TIME PLOTTING
2 TOGGLE PROMPTING
3 GIVE TITLE TO GRID
4 CHANGE CURRENT GRID BLOCK SIZE
5 CHANGE MAXIMUM GRID SIZES
6 CHANGE CURRENT BLOCK NUMBER
7 CHANGE MAXIMUM NUMBER OF BLOCKS
8 TOGGLE GRID GENERATION MODE
9 INITIALIZE DATABASE
10 INITIALIZE ZONAL INFORMATION
11 VIEW NON-BLOCK GRID
12 VIEW ONE BLOCK
13 VIEW ALL BLOCKS
14 EXIT INITIALIZATION
15 QUIT GRID GENERATION

INPUT OPTION NUMBER
BOUNDARY SEGMENT DEFINED BY

1. A CURVE PROJECTED ONTO A PARALLEL PLANE
2. OTHER CURVE PROJECTION OPTIONS
3. A STRAIGHT LINE
4. A 3D BEZIER / HERMITE CUBIC CURVE
5. SCULPTURED CURVE DEFINITION
6. CURVE MANIPULATION OPTIONS

INPUT OPTION NUMBER
GENIE++

- Semi-Interactive - Simple Minded
- Portable, Modular
- Journal File Execution Control
- Batch-Interactive Execution
- CadType Geometry Construction
- SOA Grid Generation Algorithms
- Quality Control & Extensive Error Checking
- Online Graphical Visualization of Overall Process
- User Friendly & Researcher Friendly
- SGI, X-Window, PC Versions
- bsoni@erc.msstate.edu