GENIE++ - A Multi-Block Structured Grid System

by

Tonya Williams, Naren Nadenthalan, Hugh Thornburg, and Bharat K. Soni
NSF Engineering Research Center for
Computational Field Simulation
Mississippi State University
Mississippi State, MS 39762

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.
GRID INFLUENCE

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

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

1. Algebraic Grid
2. Surface Grids and Patches
3. Geometry Definition
4. Distribution of Points
5. Mapping Physical Space → Computational Space
6. Refined Grid
STRETCHING FUNCTIONS

\[ \star \text{ Exponential} \rightarrow f(x) = \frac{e^x - 1}{e - 1} \]

\[ \star \text{ Hyperbolic Tangent} \rightarrow f(x) = 1 + \frac{\tanh(\alpha(x-1))}{\tanh \alpha} \]

\[ \star \text{ Hyperbolic Sine} \rightarrow f(x) = 1 - \frac{\sinh(\alpha(1-x))}{\sinh \alpha} \]
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

$G(I1 \rightarrow I2, \rightarrow J1 \rightarrow J2, K1 \rightarrow K2)$

Curve $[G(I1 \rightarrow I2, J \rightarrow J, K \rightarrow K)]$

A Surface $[G(I1 \rightarrow I2, J1 \rightarrow J2, K \rightarrow K)]$

A Volume $[G(I1 \rightarrow I2, J1 \rightarrow J2, K1 \rightarrow K2)]$
GENIE
Grid Generation Process / Geometry Definition

Volume
Physical Configuration

Sub-Volumes

Contiguous Blocks

Surfaces

Surfaces Patches

Boundary Segments
GEOMETRY GENERATION

- Semi-Interactive Construction
- 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, Patch, 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
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

Distribution Space
Computational Space
50 x 40

(i, j)

(s_{ij}, t_{ij})

(x_{ij}, y_{ij})
GENERAL ELLIPTIC
GENERATION SYSTEM

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

\[
g^{il} = \frac{1}{g} (g_{jm} g_{kn} - g_{jn} g_{kn}) \quad i, j, k = 1, 2, 3; (i, j, k) \text{ and } (l, m, n) \text{ cyclic}
\]
EVALUATION OF FORCING FUNCTIONS

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

\[ q = 1, 2, 3 \]

\[ \cos \theta \cdot \frac{\mathbf{r}_i \cdot \mathbf{r}_j}{\|\mathbf{r}_i\| \|\mathbf{r}_j\|} = \mathbf{s}_i \cdot \mathbf{s}_j = 0 \]
GENIE++
Characteristics
GENIE++

Geometry Mode

- Sculptured Curves and Surfaces

Computational Mode

- 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
Generic Launch Vehicle (41x41x5, 61x91x5) M = 0.3
F15e Blocking Strategy
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