Overview of Capabilities of Suggar++ With Emphasis on Recent Improvements

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Outline

- Brief overview of capabilities
- Details on what is new
  - Integrated USURP
  - Periodic passage: Turbine blade row
  - 650 million grid point grid system
  - High-order overset interpolation
- Summary

BRIEF
SUGGAR++ OVERVIEW

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Suggar++ Overview

- Built upon experience with SUGGAR
  - Complete rewrite
  - Improved algorithms
- Significantly better than SUGGAR
  - Performance: memory and speed
  - New capabilities
- Integrated with new Pointwise OGA capability

Suggar++ Overview

- Node- and/or cell-centered assembly
- Grid types
  - Structured: Curvilinear and Cartesian
  - Unstructured
    - Tet, Mixed element, Octree
    - General polyhedral to be added in future

Suggar++ Overview

- Hole cutting
  - Direct cut, analytic, octree, manual
- Integrated surface assembly
  - Structured and/or mixed element grids
- Overlap minimization using general Donor Suitability Function
  - Including distance-to-wall
- Support for arbitrary structured solver stencil

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Suggar++ Overview

- Hybrid parallel execution
  - Threads and/or MPI
  - Decomposition of structured or unstructured grids
- Unstructured grid refinement
- Designed for moving body problems
- Link into flow solver for integrated dynamic OGA
  - Dynamic Groups: hide OGA execution time

Suggar++ Overview

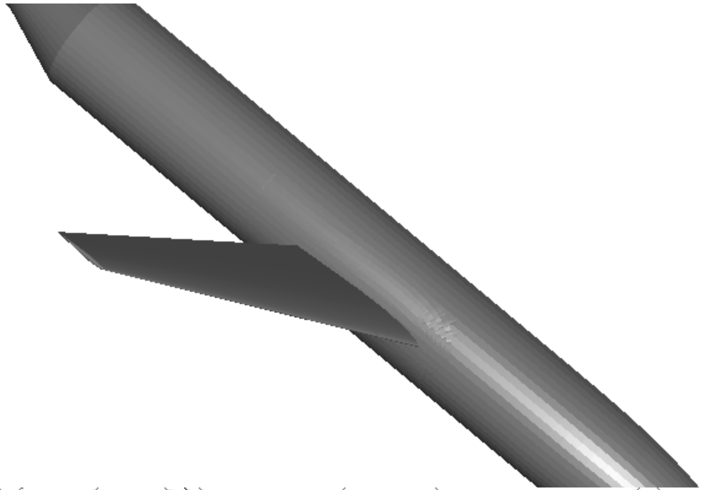
- Integrated USURP to support F&M integration
- Periodic passages
- High-order support
  - Arbitrary number of fringes
  - High-order interpolation for structured grids

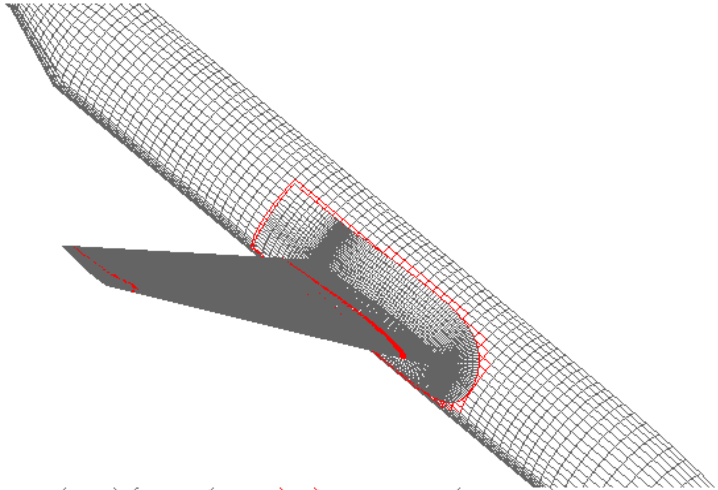
INTEGRATED USURP CAPABILITY

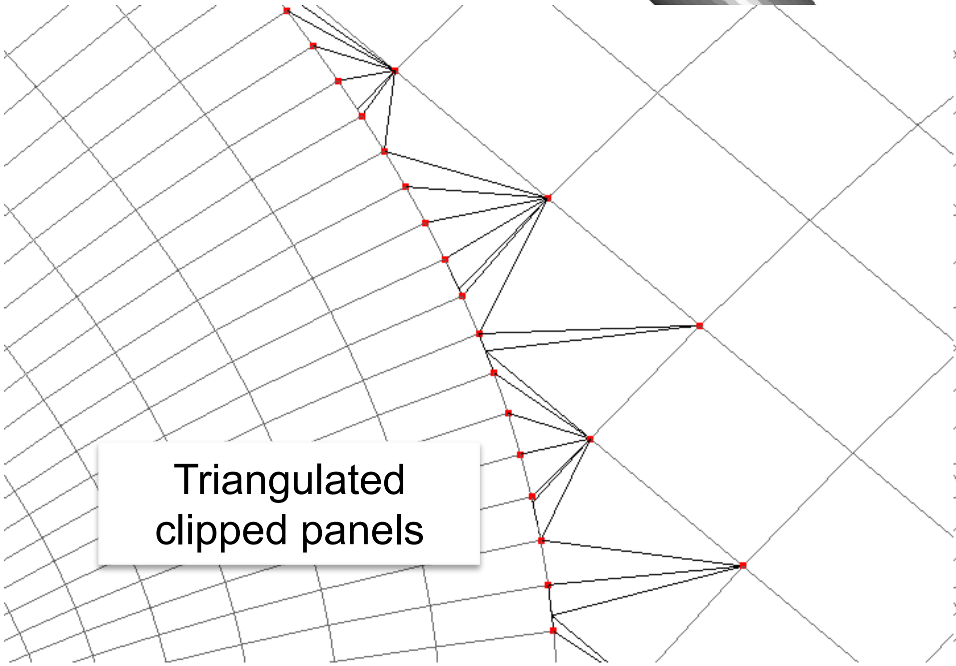
Integrated USURP capability

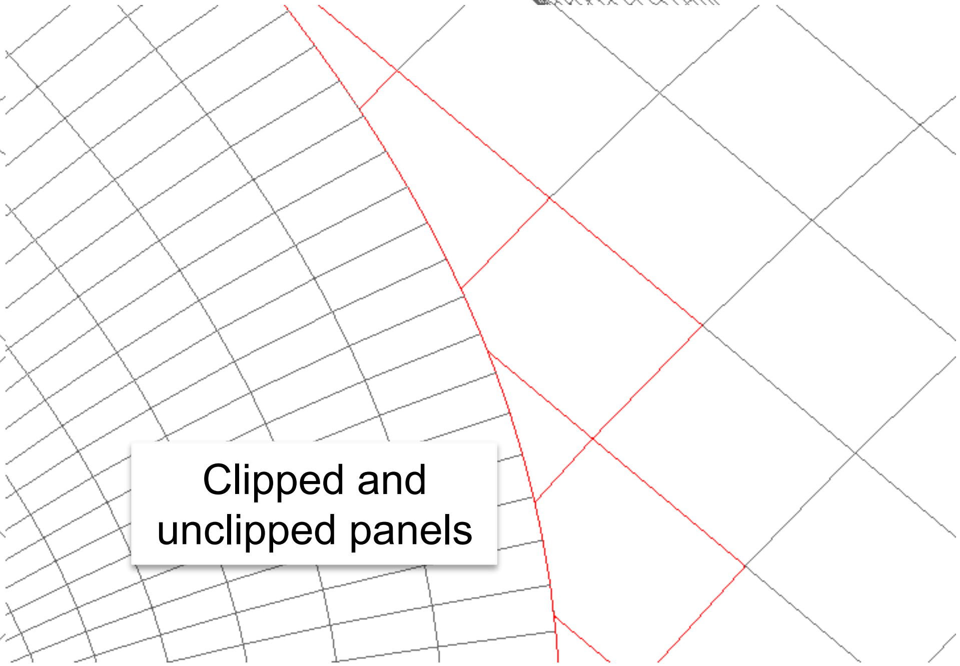
- Similar but not identical to the USURP utility
  - Different coding
  - Uses CLIPPER for polygon clipping
    - More robust than GPC used in USURP
  - Triangulation routines are different than USURP
- Panel weights
  - Included in DCI file: Can be retrieved via DiRTlib
  - Written to files
- Can create zipper grid
  - Not sufficiently robust

Suggar++ USURP output for WingBody

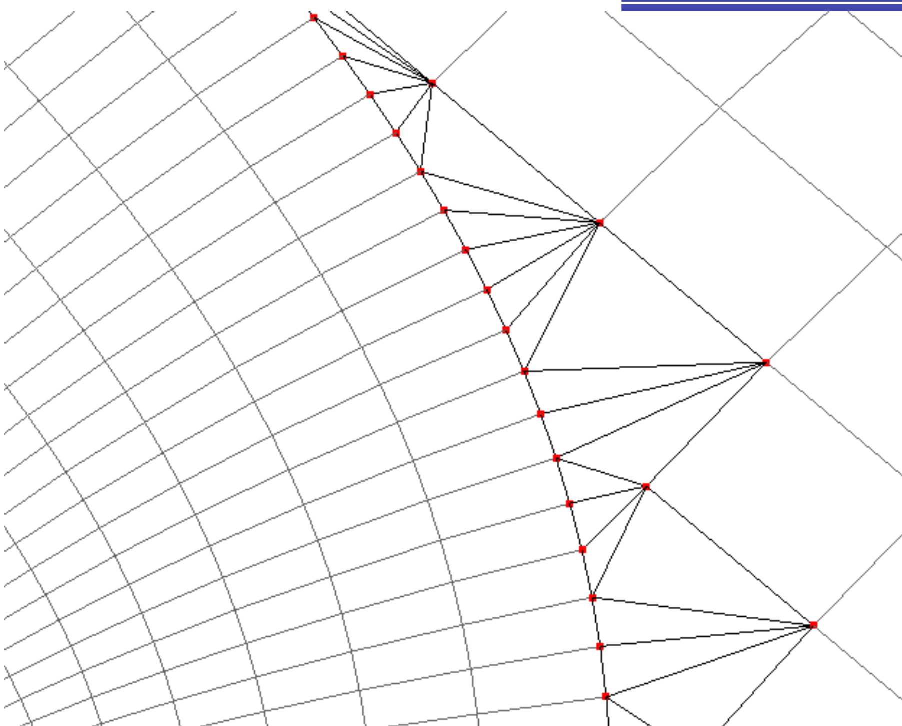




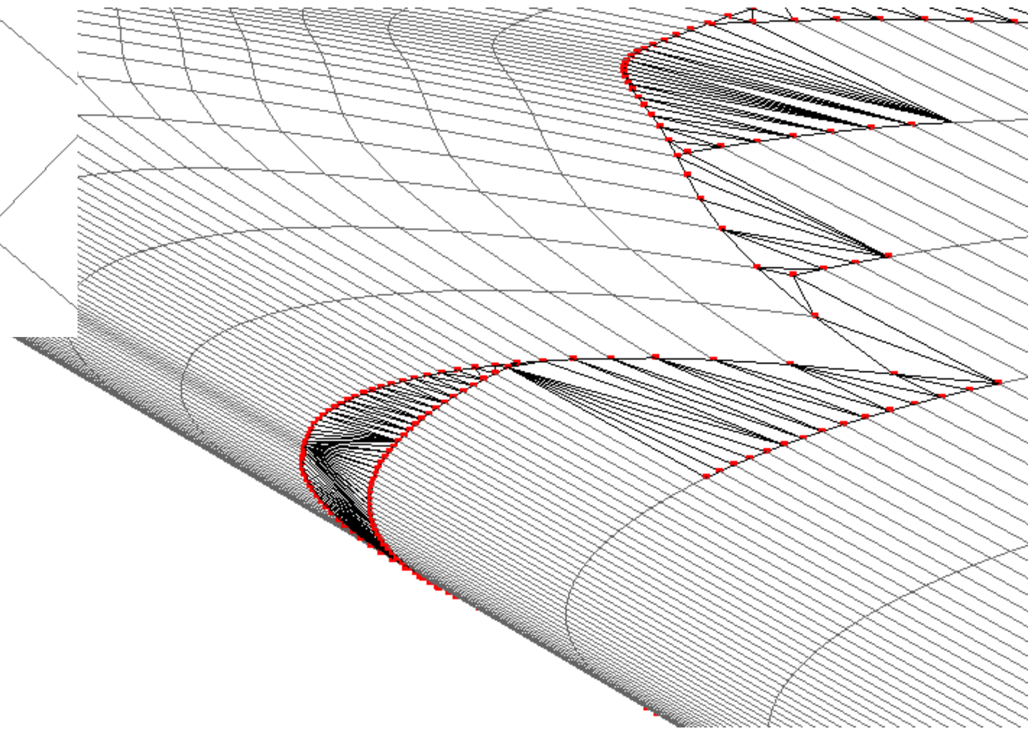




Suggar++ USURP output for WingBody



Zipper grid:
Triangles contain only points in the original grid



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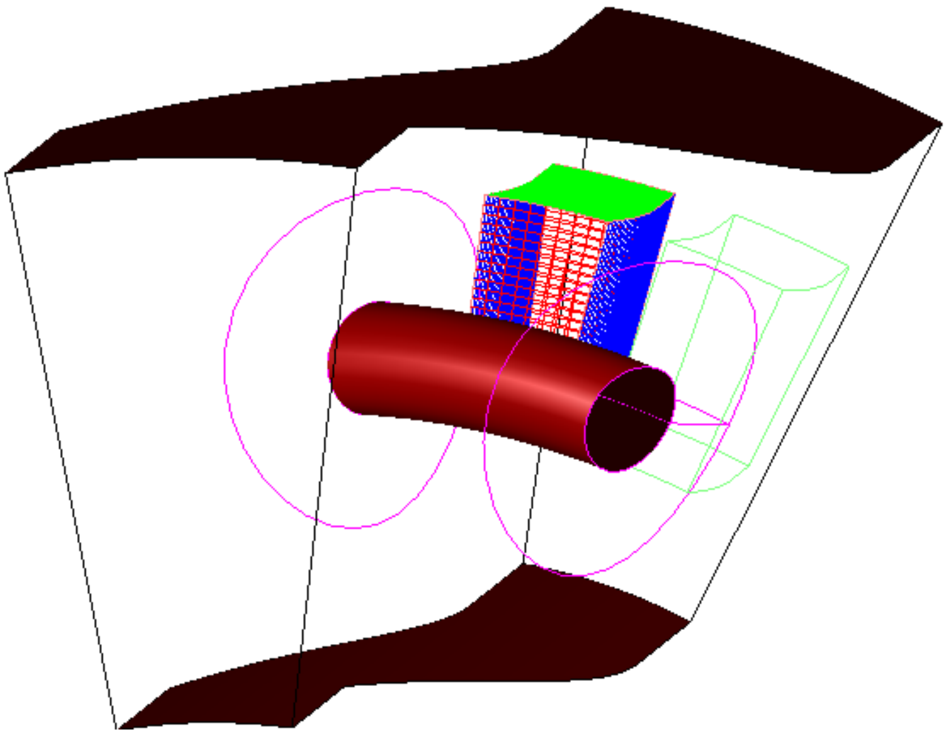
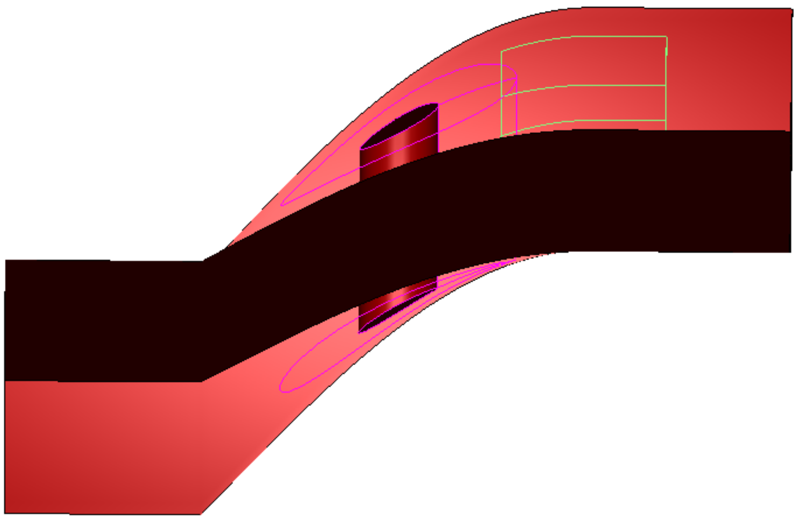
PERIODIC PASSAGE CAPABILITY

Periodic Passage

- Simulate one blade row out of full wheel
- Typically non-planar periodic boundary surfaces
- Flow solver uses periodic boundary conditions to simulate effect of all blades

Periodic passage





Periodic Passage: Complexities For Overset

- Donor stencil member can be across periodic boundary
  - Virtual donor member grid: flow solver must transform velocities
- Grid can extend into neighboring passage
  - Donor search must extend into virtual grid
    - Not yet implemented
- DCI must be consistent across boundaries

Periodic Passage: Complexities For Overset

- Grids that overlap on passage boundary will have different representations of passage boundary
  - Treatment to prevent flood fill leaks along passage boundary
  - May need surface assembly to keep points inside passage
    - Ignored to be consistent with full wheel/non-periodic grid system

SUGGAR++ EXECUTION OF VERY LARGE GRID SYSTEM

Suggar++ Execution of Very Large Grid System

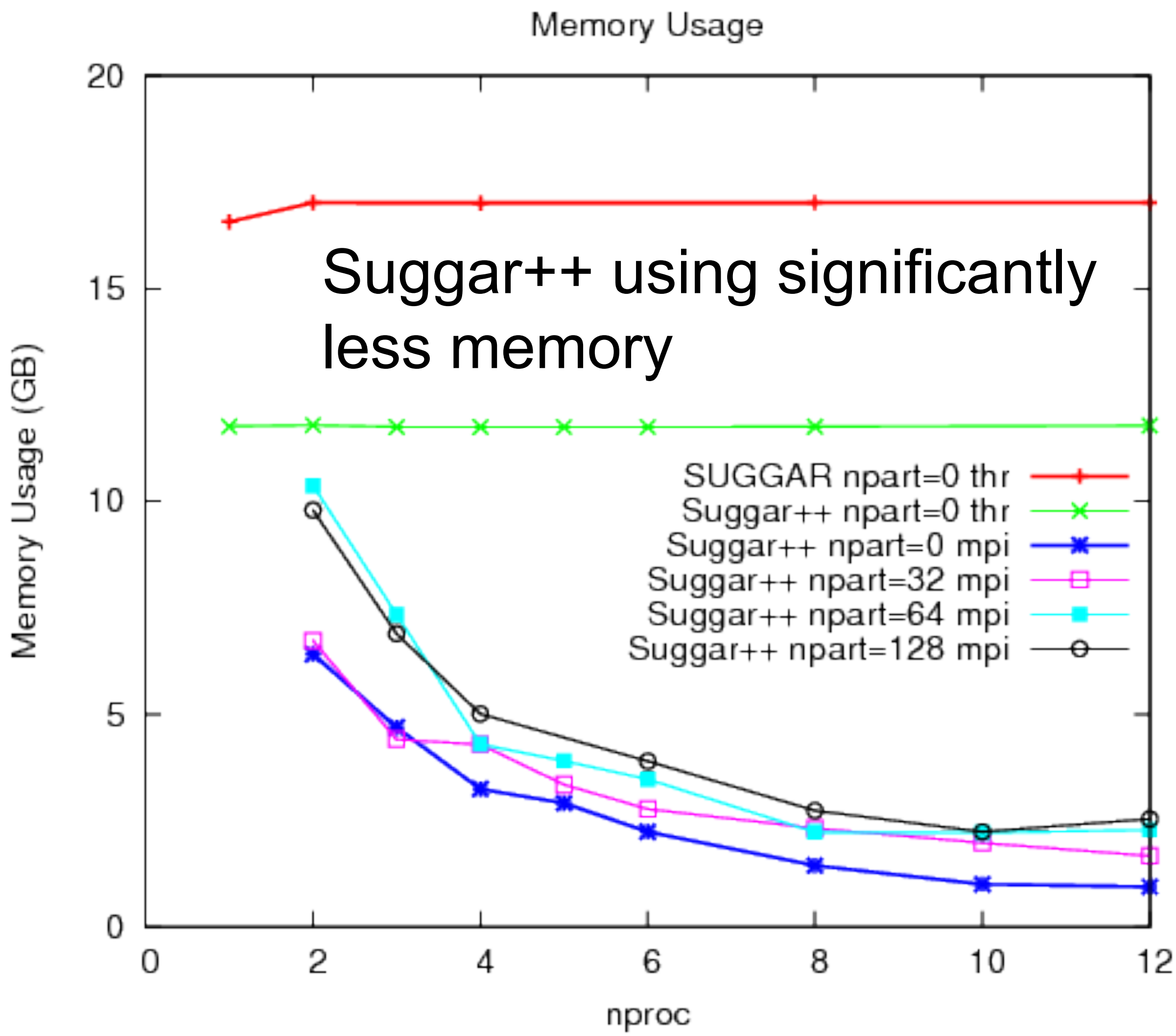
- Athena grid system obtained from Pablo Carrica (U. Iowa/IIHR)
  - Appended, propeller, moving rudder, refinement grids
  - Plane of Symmetry
  - Provided Medium and Fine grid systems

Set Of Grid Systems

- Started with Medium and Fine grid systems
- Mirrored and refined to get larger systems
  - Refined by factor of 2 in each direction

Case	Number of grid points
Medium	14,374,923
Medium-mirrored	28,749,846
Medium-mirrored-refined	225,434,040
Fine	40,871,388
Fine-mirrored	81,742,776
Fine-mirrored-refined and partitioned	653,279,190

Memory Usage
Fine Grid: ~40 Million points



Fine-mirrored-refined: Preliminary Results

- Used 20 nodes and only one thread/node
  - Limit of available nodes
  - Used only one thread to limit memory usage
  - Max memory used was 22 GB
    - Nodes had 24 GB memory
    - Probably paging with degraded performance
- Time and resources did not permit a detail performance analysis
  - Successful feasibility demonstration

HIGH ORDER OVERSET INTERPOLATION

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High Order Overset Interpolation

- Suggar++ has had the ability for an arbitrary number of fringe levels from the beginning
- Added high-order interpolation using Lagragian polynomials
  - Using Lagrangian Polynomial approach of Scott Sherer
  - Implemented for Node- and Cell-Centered assemblies

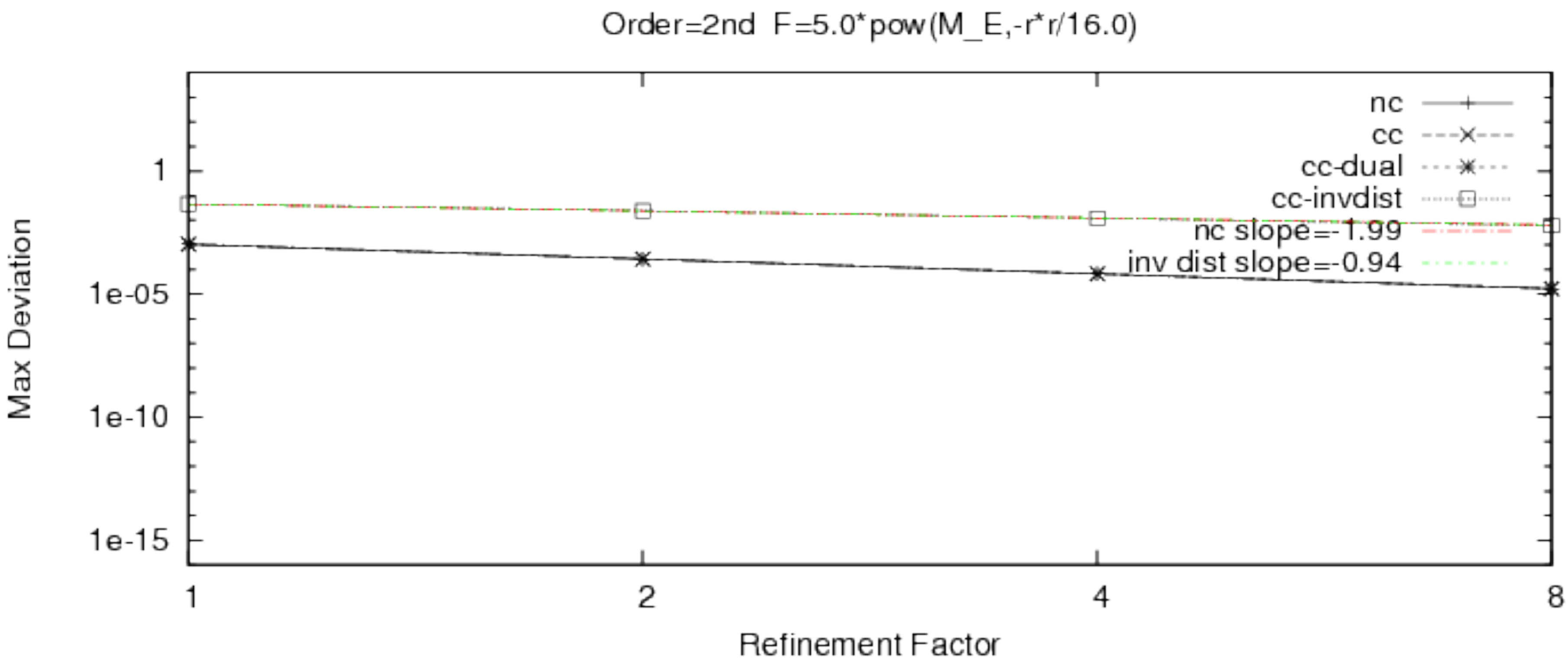
High-Order Overset Interpolation Examination of Accuracy

- Suggar++ supports a Monitor Grid
  - A set of points where all points/cells are fringes
  - Useful for interpolating solution onto a new grid
  - Examine solution at specific points
- Examine order of accuracy of high order interpolation
  - Background/donor grid system
    - Series of grids refined by factor of 2 in each direction
  - Dependent variables will be analytic functions
    - Linear
    - Polynomial of varying order
    - Exponential, analytic vortex
  - Monitor grid to obtain interpolated values at set of locations
  - Find the maximum deviation between the interpolated and exact

High Order Interpolation
Single Grid

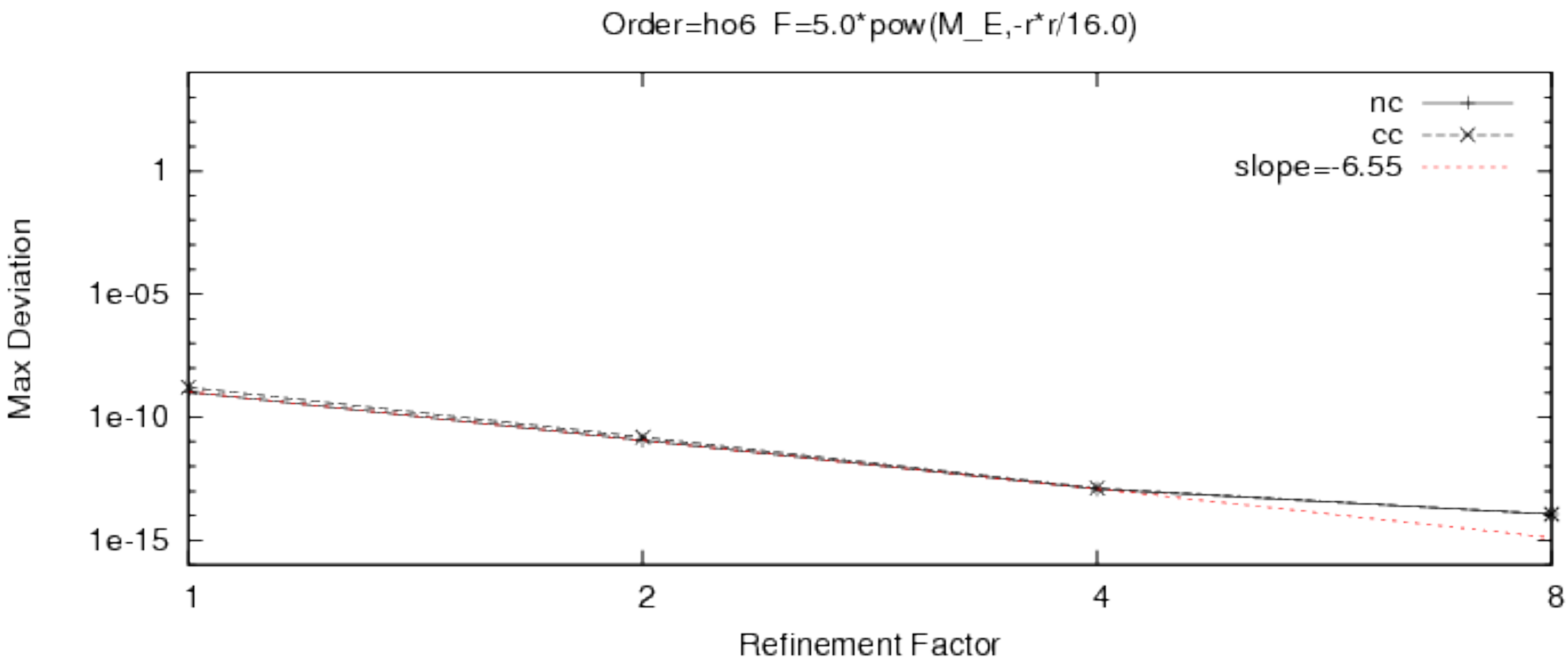
- Single uniform Cartesian donor grid
- Monitor grid is a randomly perturbed set of points
  - To prevent fortuitous alignment
- Only show results for analytic vortex
- Convergence slope is computed using gnuplot

2^{nd} Order Interpolation Single Grid Results



- Inverse distance weighting is first order
- Least square, dual hex, trilinear are 2^{nd} order

6^{th} Order Interpolation Single Grid Results



- 6 point Lagrangian polynomial is 6^{th} order

Block-to-Block Grid Systems

- Block-to-Block grid systems arise from
  - Grid generation
  - Grid decomposition/splitting

- How does this affect high-order interpolation?

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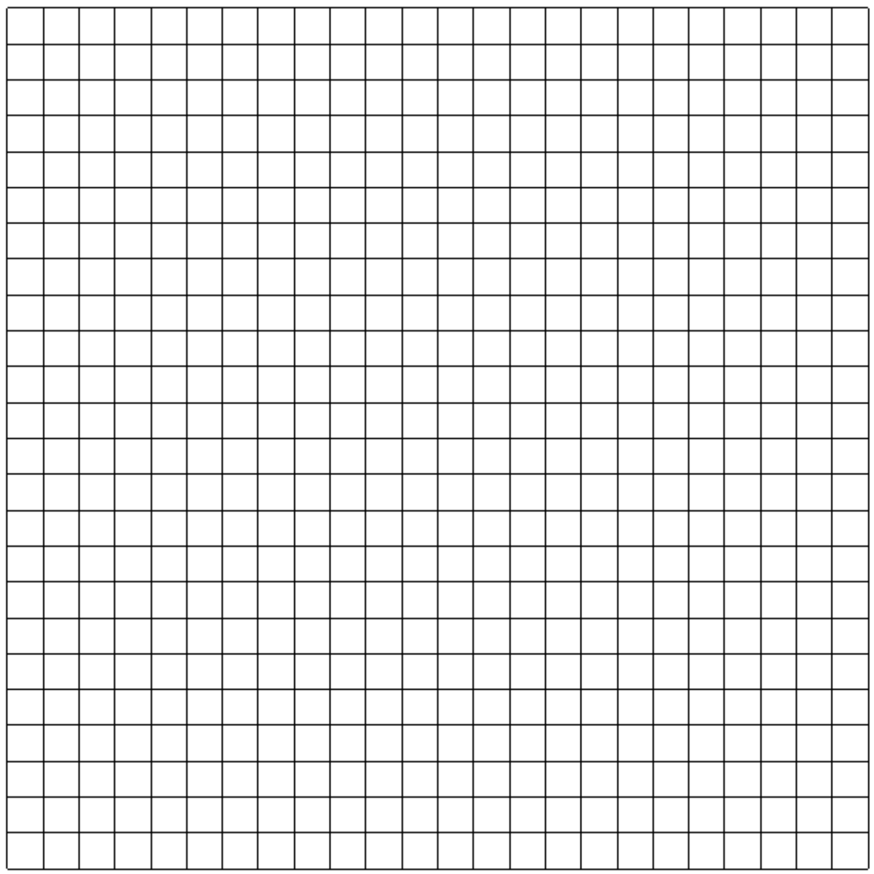
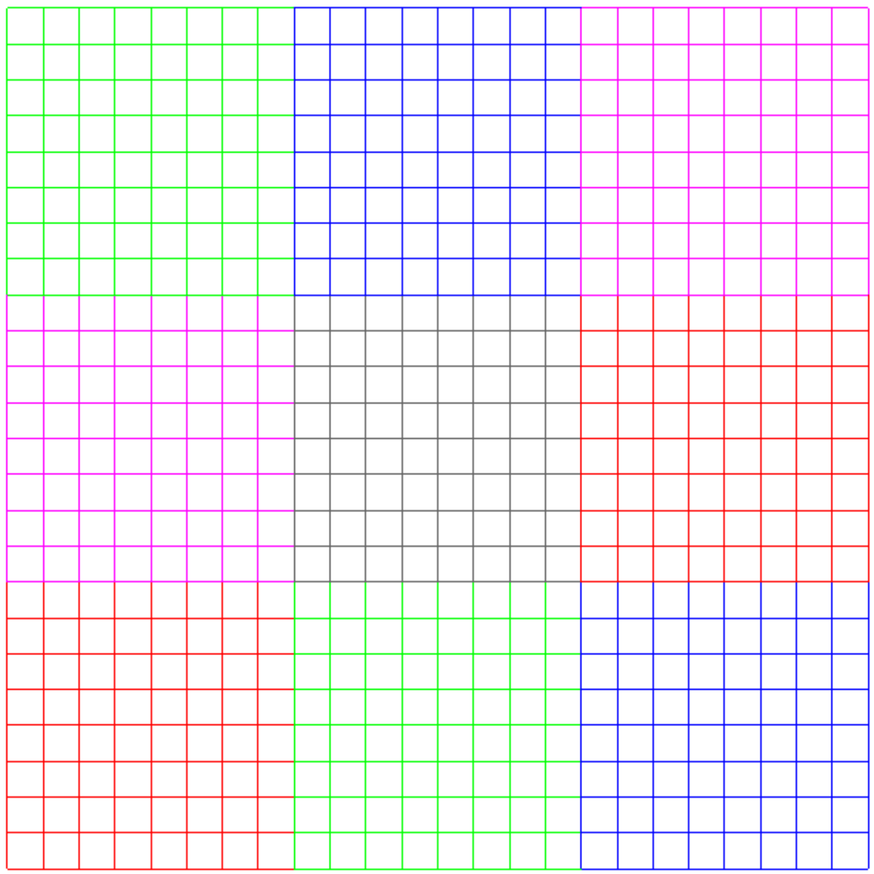
Consider A Single Grid



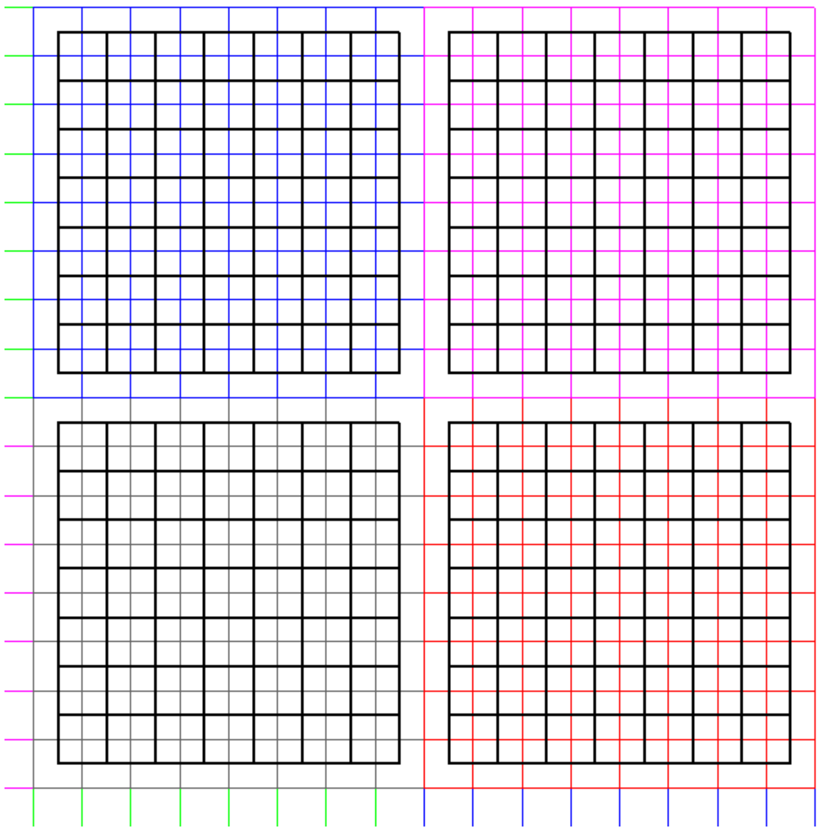
Decompose Into Block-to-Block Grid System



Cell-Centered High-Order

- Cell-centered high-order interpolation uses dual grid
  - Structured grid connecting cell centers

Cell-Centered Dual Grid



- Dual grid does not cover volume
- Will require extrapolation

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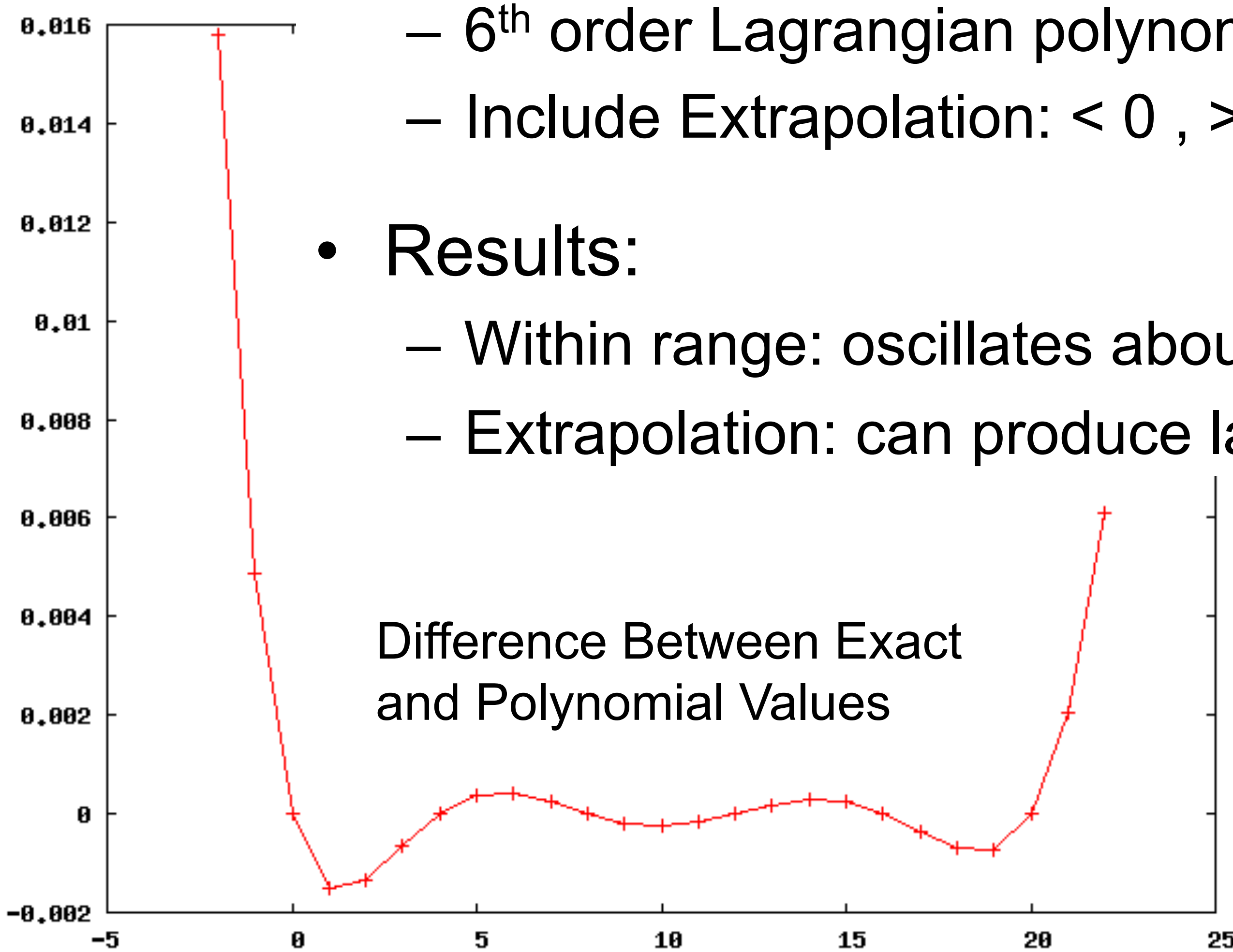
Lagrangian Polynomial with Extrapolation

- Analytic Vortex
  - 6^{th} order Lagrangian polynomial
  - Include Extrapolation: < 0 , > 20
- Results:
  - Within range: oscillates about exact
  - Extrapolation: can produce large deviations



Difference Between Exact and Polynomial Values

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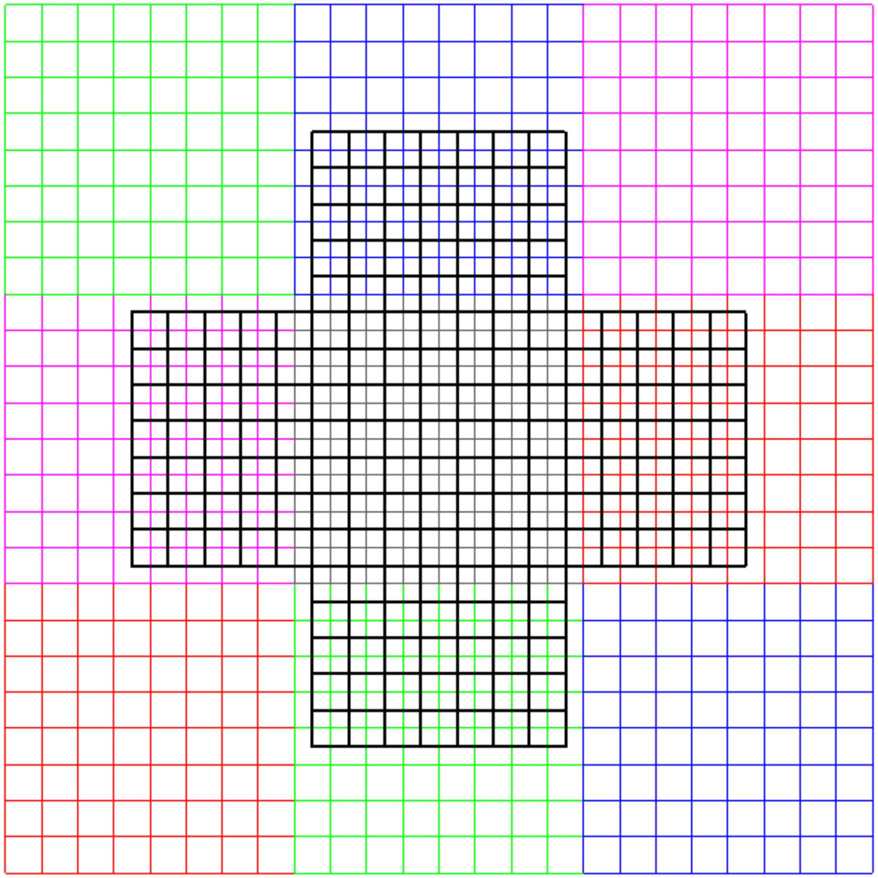
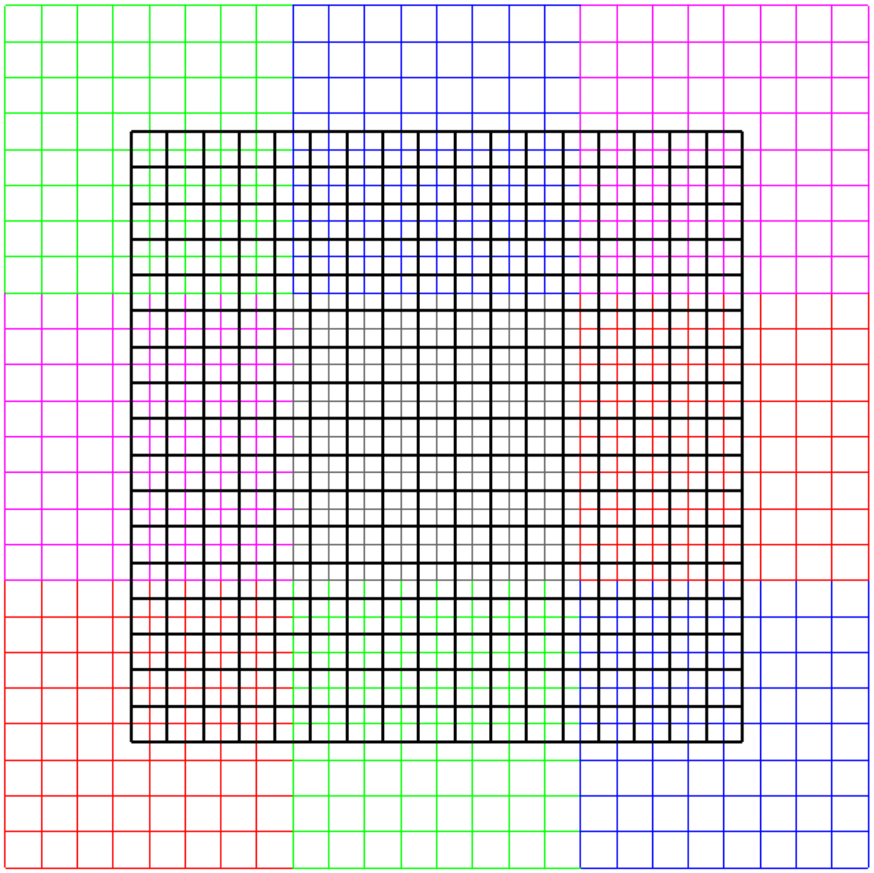
Use “Extended Grid“

- Extend grid into neighboring block-to-block grids
- First into block-face neighbors

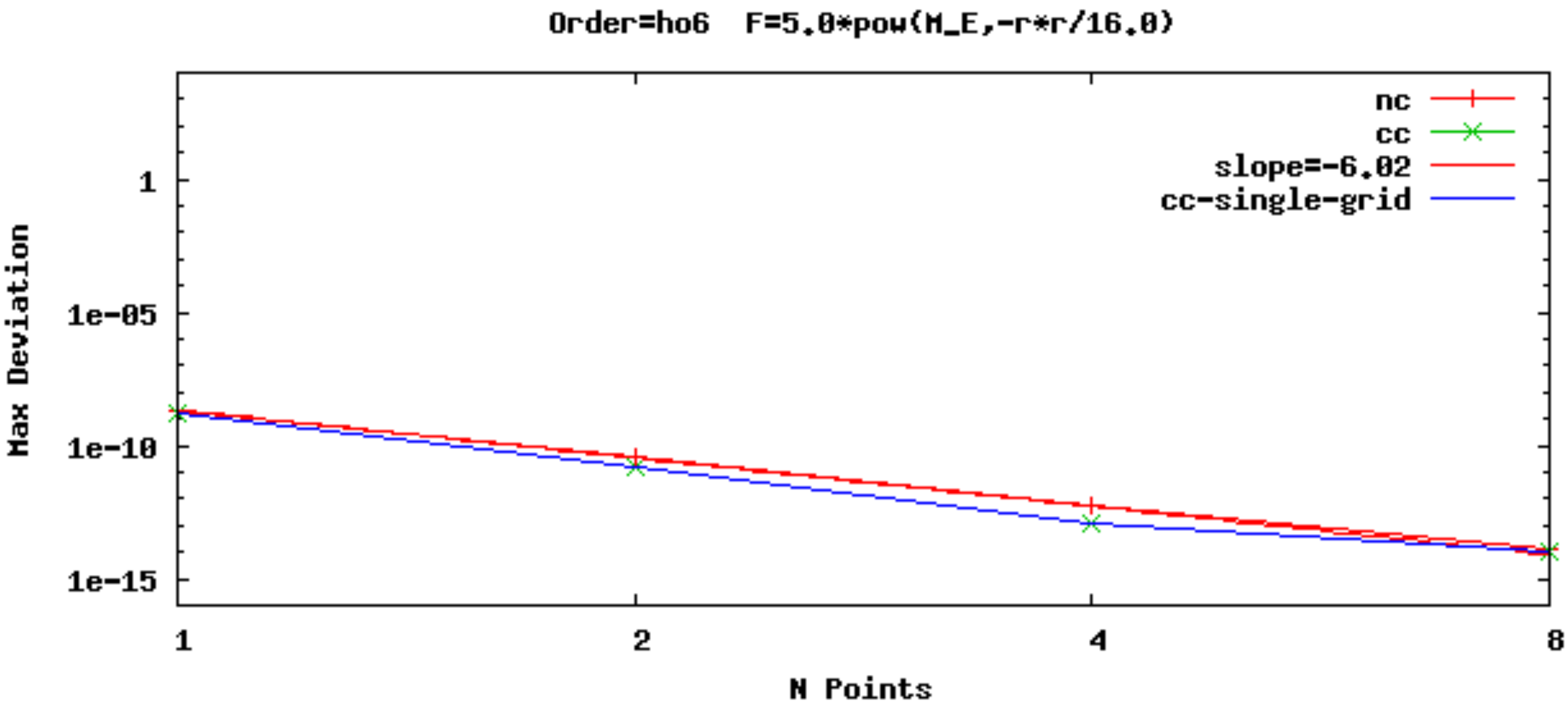


Use “Extended Grid“

- Extend grid into neighboring block-to-block grids
- Next across edges and corners



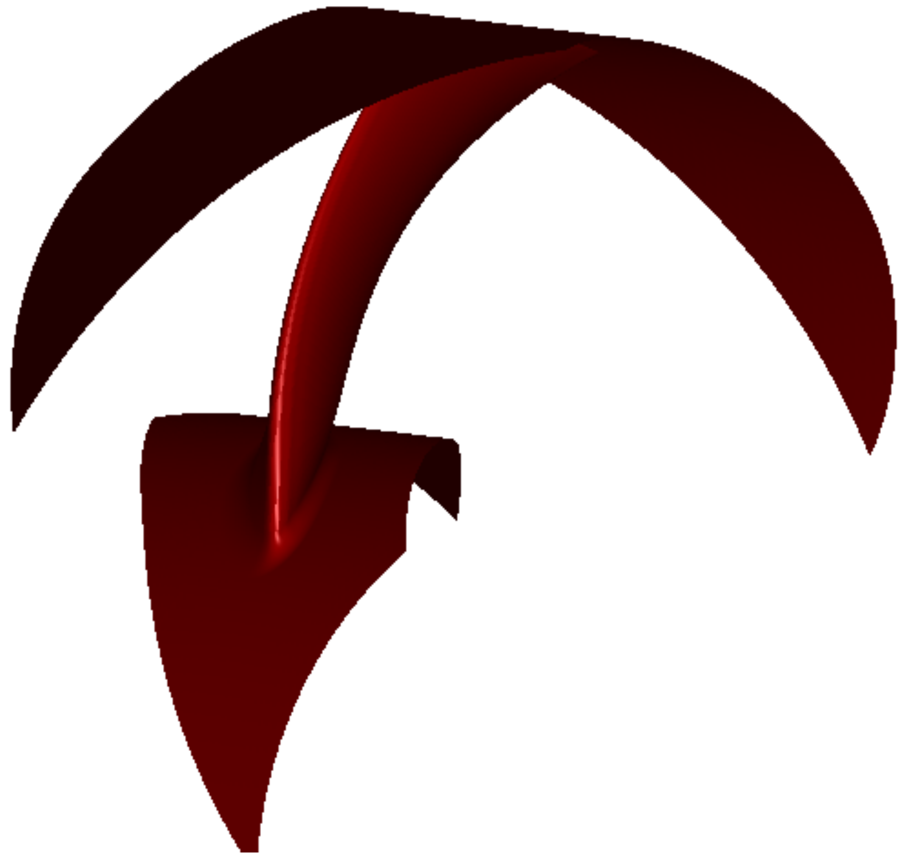
6^{th} Order Interpolation Extended Grid Results



- Extended grid yields same results as single grid

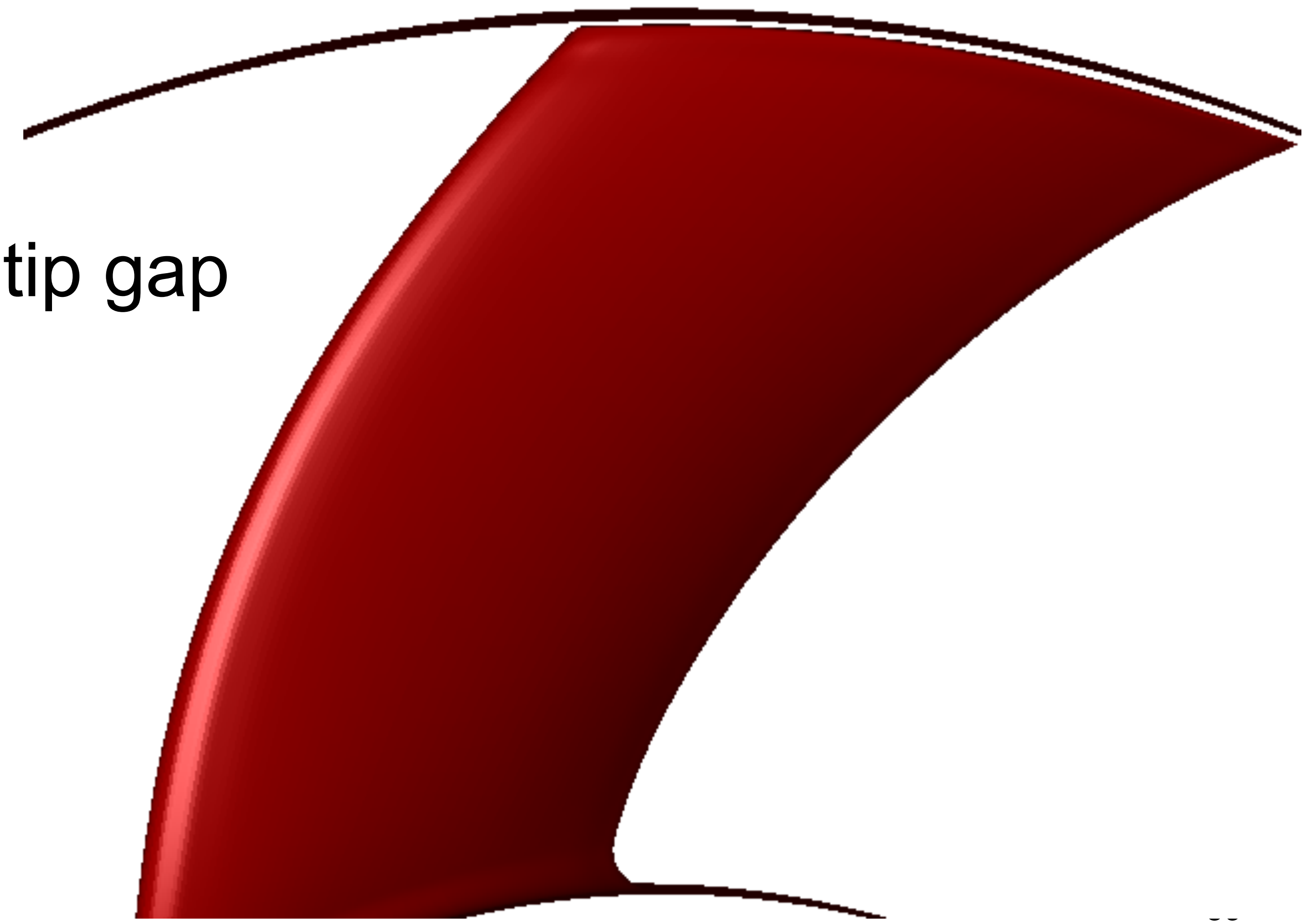
Real World: Turbine Blade

- Single blade
  - Periodic passage
- Cell-centered Block-to-block grids
- Passage boundaries are not displayed



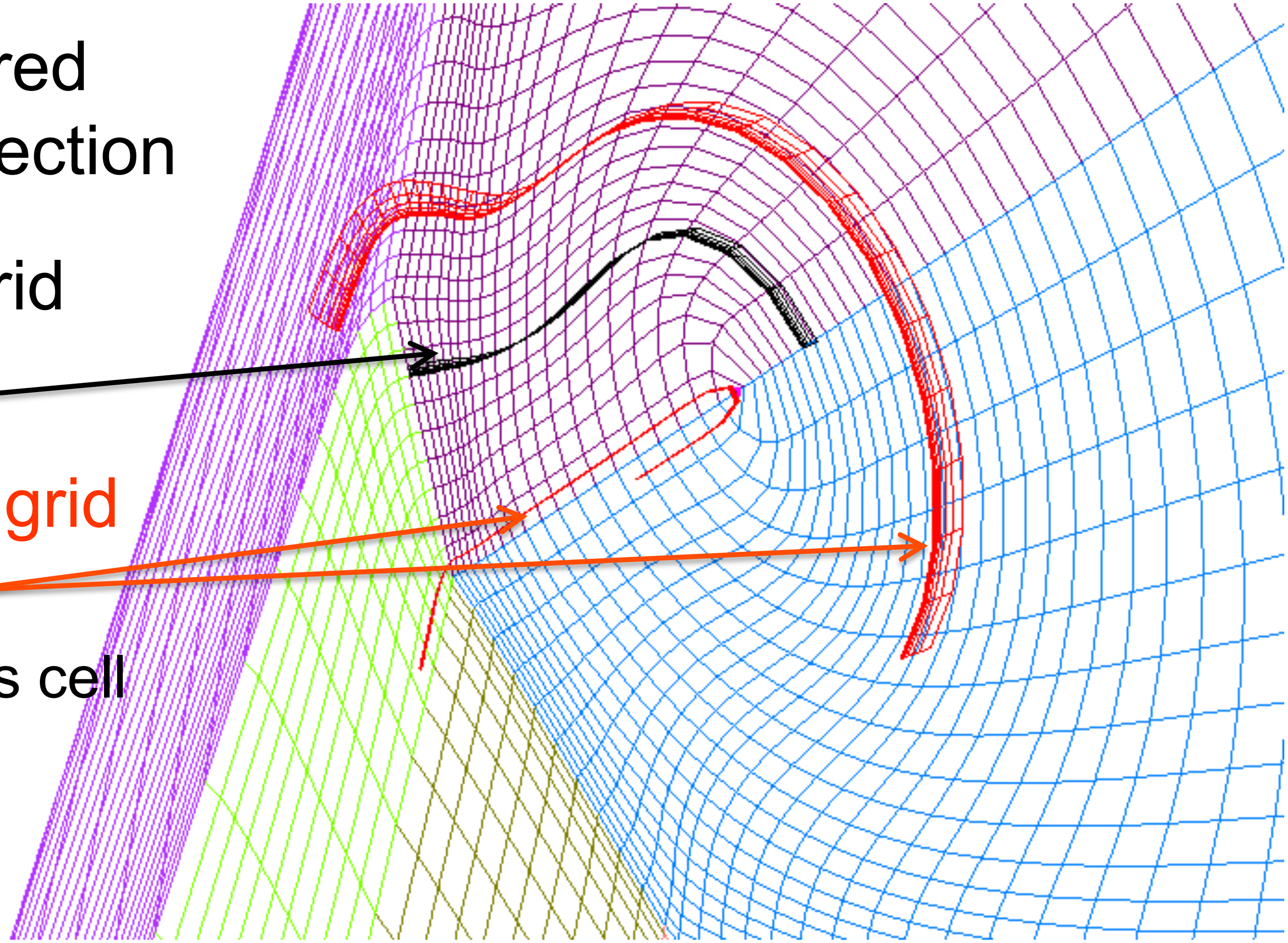
Real World: Turbine Blade

- Small tip gap

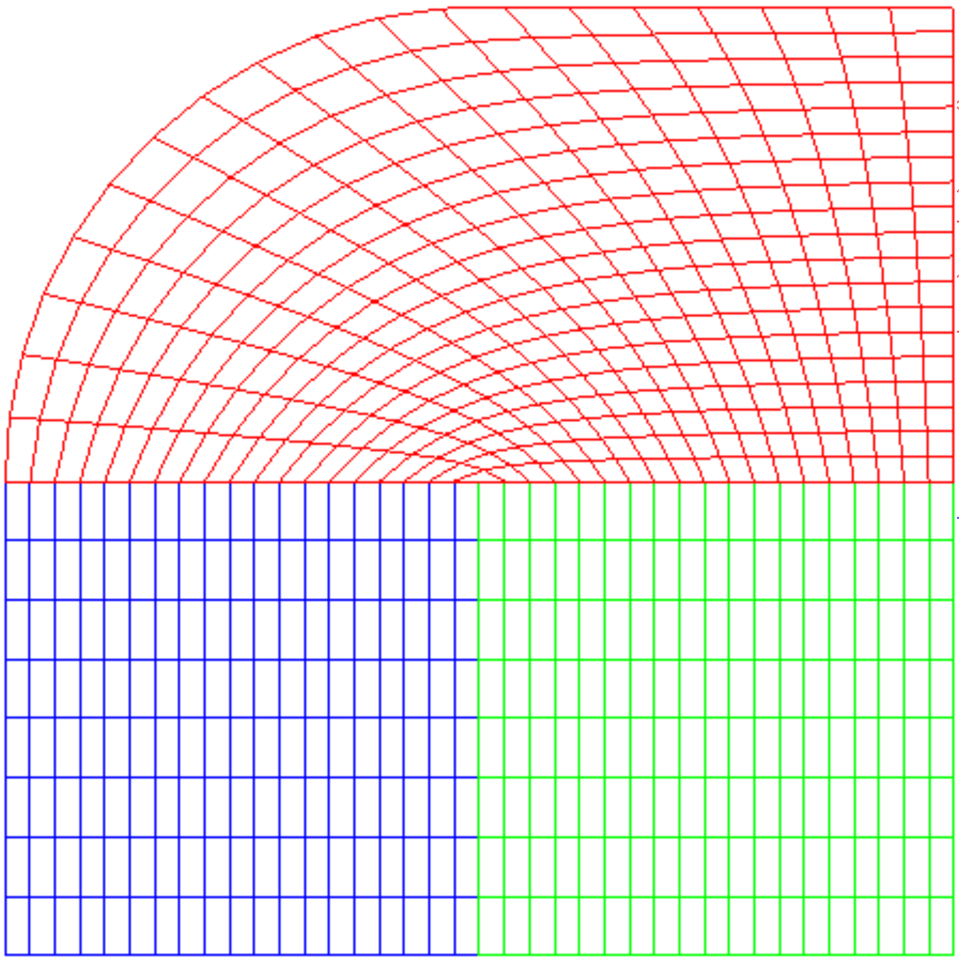


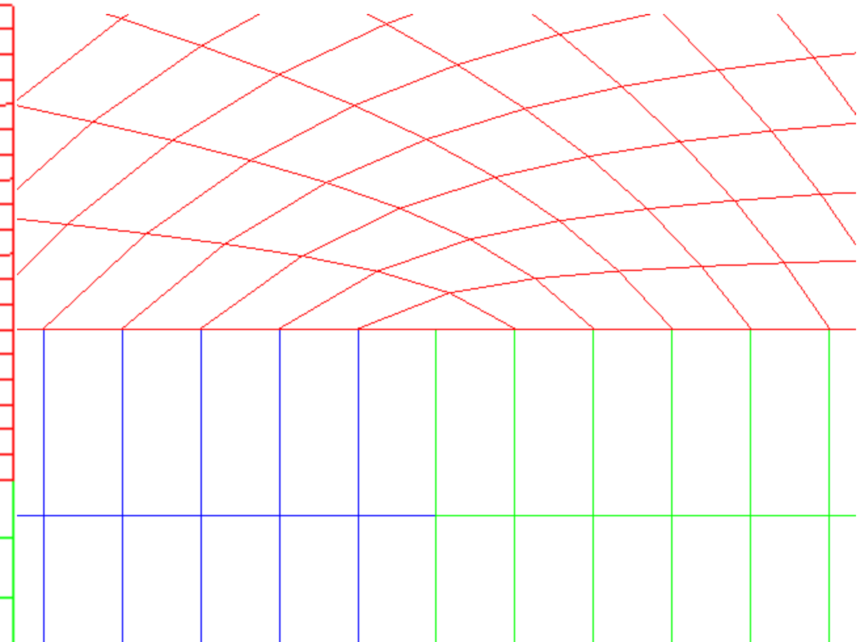
Real World: Turbine Blade

- Unstructured B2B connection
- Primary grid plane
- Extended grid planes
  - Connects cell centers



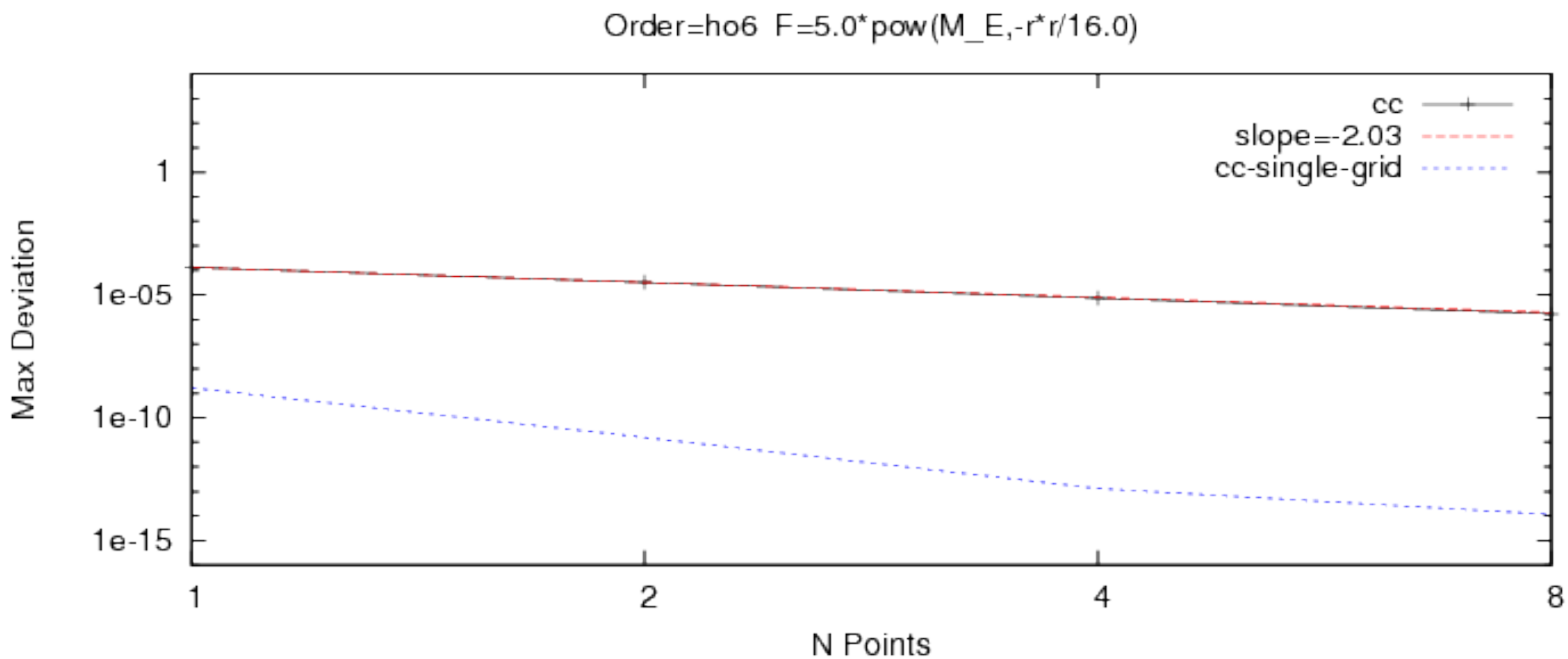
Simplified Grid System





- Cannot fully extend grid
- Leaves void where extrapolation is required

Void in Extended Grid Reduces Accuracy



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Overlapping Surfaces & High-Order Interpolation

- Surface assembly required to "shift/project" fringes into donor grid
- Bilinear surface representation not appropriate for high-order interpolation
  - Must use high-order polynomial representation
- Cell-centered assembly must use dual surface
- Viscous spacing + stretching + high-order
  - Sensitive and difficult problem
  - Not happy with the current results

SUMMARY

Summary

- Suggar++ is the most general overset grid assembler available
- Significant improvement over SUGGAR
- New capabilities were presented
  - Integrated USURP
  - Periodic passage
  - High-order interpolation
- Demonstrated execution for very large grid system

Summary(2)

- Presented difficulties with high-order interpolation for cell-centered assemblies
  - Dual grid does not cover domain
  - Extended grid can recover single grid results
  - Block-to-Block topologies can leave regions without extended grid
    - Adversely affects interpolation accuracy
- Recommend node-centered approach for high-order overset solutions

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