

New Challenges in Grid Generation and Adaptivity for Scientific Computing



New Challenges in Grid Generation and Adaptivity for Scientific Computing (SEMA SIMAI Springer Series

Book 5) by Gary K. Rockswold

★★★★☆ 4.4 out of 5



Language : English
File size : 14857 KB
Print length : 333 pages
Screen Reader : Supported



Grid generation and adaptivity are fundamental aspects of scientific computing, enabling the accurate and efficient solution of complex computational problems across diverse scientific and engineering disciplines. From simulating turbulent fluid flows to modeling the intricate behavior of materials, the ability to generate high-quality grids and adapt them dynamically to changing conditions is crucial for obtaining reliable and meaningful results.

In recent years, the advent of high-performance computing and the increasing complexity of scientific models have spurred the development of innovative grid generation and adaptivity techniques. This article explores the latest challenges and advancements in these areas, providing a comprehensive overview of the state-of-the-art.

Challenges in Grid Generation

Grid generation involves creating a mesh of points that discretizes the computational domain. The quality of the grid significantly impacts the accuracy and efficiency of the simulation. Key challenges in grid generation include:

- **Geometric complexity:** Handling complex geometries with intricate features or sharp boundaries poses challenges for grid generation algorithms.
- **Anisotropic features:** Capturing anisotropic features, such as thin layers or elongated structures, requires grids that align with the dominant flow or deformation directions.
- **Scale disparity:** Simulating problems with widely varying scales, such as molecular dynamics or multi-scale models, requires grids that can resolve both small and large-scale features.

Advancements in Grid Generation

To address these challenges, researchers have developed novel grid generation techniques, including:

- **Unstructured grid generation:** Unstructured grids allow for greater flexibility and adaptability compared to structured grids, enabling the efficient meshing of complex geometries.
- **Adaptive mesh refinement:** Dynamically refining the grid in areas of high interest or error, such as boundary layers or regions of high deformation, improves solution accuracy and efficiency.
- **Isogeometric analysis:** Integrating grid generation with the geometric representation of the domain, using NURBS or other spline-based methods, simplifies meshing and improves solution quality.

Challenges in Adaptivity

Adaptivity involves dynamically adjusting the grid based on the evolving solution or computational requirements. This poses challenges, such as:

- **Timeliness:** Adapting the grid in a timely manner, especially in real-time simulations, is crucial to maintain accuracy and stability.
- **Load balancing:** Ensuring efficient load balancing during grid adaptation, particularly on massively parallel computing platforms, is essential for performance.
- **Robustness:** Adaptivity algorithms should be robust to maintain grid quality and prevent mesh tangling or other numerical instabilities.

Advancements in Adaptivity

Significant progress has been made in adaptivity research, leading to advancements such as:

- **Error-based adaptivity:** Adapting the grid based on local error estimates, ensuring that regions of high error are refined.
- **Physics-based adaptivity:** Exploiting knowledge of the underlying physics to guide grid adaptation, improving accuracy and capturing important phenomena.
- **Goal-oriented adaptivity:** Tailoring the adaptation process to specific output quantities of interest, optimizing the grid for targeted metrics.

Applications in Scientific Computing

Grid generation and adaptivity have broad applications in scientific computing, including:

- **Computational fluid dynamics:** Simulating complex fluid flows in engineering, aerospace, and environmental applications.

- **Computational solid mechanics:** Modeling the behavior of solids under various loading conditions, including stress analysis and fracture mechanics.
- **Computational electromagnetics:** Solving Maxwell's equations to analyze electromagnetic fields in antennas, waveguides, and other devices.

Grid generation and adaptivity remain vital areas of research and development in scientific computing. The ongoing advancements in these technologies enable researchers and practitioners to tackle increasingly complex and challenging computational problems. By leveraging the latest innovations in grid generation and adaptivity, we can unlock new possibilities in scientific discovery and engineering design.

References

1. J. Peraire and J. Peiró, "Adaptive Refinement for Unsteady Compressible Flow Problems," *AIAA Journal*, vol. 40, no. 3, pp. 569-581, 2002.
2. T.J.R. Hughes, G.R. Feijóo, L. Mazzei, and J.B. Quincy, "The Variational Multiscale Method - A Paradigm for Computational Mechanics," *Computer Methods in Applied Mechanics and Engineering*, vol. 166, pp. 3-24, 1998.
3. Y. Bazilevs, V.M. Calo, T.J.R. Hughes, and Y. Zhang, "Isogeometric Fluid-Structure Interaction Analysis with Applications to Arterial Blood Flow," *Computational Mechanics*, vol. 43, no. 1, pp. 3-32, 2008.

New Challenges in Grid Generation and Adaptivity for Scientific Computing (SEMA SIMAI Springer Series



Book 5) by Gary K. Rockswold

★★★★☆ 4.4 out of 5

Language : English

File size : 14857 KB

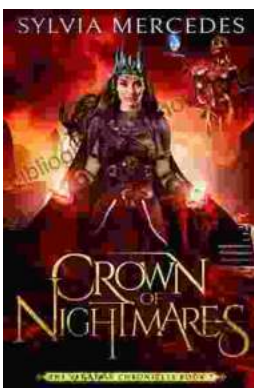
Print length : 333 pages

Screen Reader : Supported



Twenty-Eight Days on the Russian Front: A Thrilling Tale of Valor and Endurance

Witness the Unforgettable Winter Warfare Twenty-Eight Days on the Russian Front transports readers to...



Crown of Nightmares: The Venatrix Chronicles - An Epic Fantasy Adventure That Will Captivate Your Imagination

Embark on an epic journey filled with mystery, magic, and danger with Crown of Nightmares: The Venatrix Chronicles. This captivating novel will transport you to the...