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COMPUTATIONAL PARTICLE-BASED SOLVERS FOR MULTIPHYSICS & MULTISCALE SIMULATIONS

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Computational particle-based solvers have emerged as powerful tools for conducting multiphysics and multiscale simulations, offering a comprehensive understanding of complex phenomena across scientific and engineering domains. These solvers consider particles as fundamental entities, each interacting with others and their environment, making them well-suited for addressing interconnected processes.

In the realm of multiphysics simulations, where different physical phenomena interact, particle-based solvers excel at capturing these intricate couplings. Unlike grid-based methods, which struggle with such interactions, particle-based approaches provide a more natural representation. For instance, these methods can simulate fluid dynamics, heat transfer, and electromagnetic interactions simultaneously, revealing insights into how these processes influence each other within a unified framework.

Furthermore, particle-based solvers play a crucial role in multiscale simulations. These methods allow adaptive refinement, dedicating computational resources to areas of interest while coarsening less critical regions. This adaptability enables simulations spanning several orders of magnitude, such as studying the behaviour of nanoparticles in fluid flows or the interaction between molecules in chemical reactions.

One illustrative application of particle-based solvers is in additive manufacturing (AM). AM involves intricate multiphysics phenomena, including heat transfer, fluid flow, and material behaviour. Particle-based solvers can simulate the entire AM process, capturing the deposition of material layer by layer. For instance, in metal powder-bed fusion AM, these solvers can model the interaction between laser energy and metal particles, predicting melting, solidification, and the resulting microstructure.

In AM simulations, particle-based methods address multiscale challenges. They can model the macroscopic workpiece while resolving microscale phenomena, such as grain growth and defects within individual layers. This capability is essential for predicting material properties and final part performance accurately.

Despite their strengths, particle-based solvers come with challenges. Achieving numerical stability, handling boundary conditions, and managing computational costs remain areas of active research. The growing complexity of simulations demands substantial computational resources, often requiring high-performance GPUs.

Recent advancements in parallel computing, algorithm optimization, and hardware capabilities have propelled particle-based solvers forward. Researchers are refining existing methods and developing new ones to address limitations and expand applications while coupling with other numerical techniques serve to further enhance their capabilities.

In conclusion, computational particle-based solvers are instrumental in multiphysics and multiscale simulations, providing insights into intricate phenomena. With applications like AM, these solvers showcase their ability to model complex processes and predict real-world outcomes accurately. As computational techniques continue to evolve, particle-based solvers are poised to drive scientific understanding and innovation across diverse fields.