An Optimized Multigrid Algorithm for Enabling Efficient Physical Simulations on Realistic Geometries

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Partial differential equations (PDEs) are used in physics to mathematically describe many real-world phenomena. Using computers to solve these equations allows scientists and engineers to create realistic simulations of such phenomena, ranging from the diffusion of calcium through a heart cell, to the distribution of stress on a support beam in a building, to the Einstein field equations around a black hole. However, the physics of the real world are very complex, and when solving such PDEs to accurately represent reality, existing solution methods can exhibit prohibitively long computation times. In this project, an improved PDE solver algorithm is developed to enable more efficient creation of physical simulations. Like most PDE solvers, this algorithm uses discretized models of real geometries (known as geometric meshes) to approximate physical objects and the equations that govern their behavior. However, unlike existing methods, which discard information about these meshes, the proposed algorithm creates a hierarchy of multiresolution meshes, retaining multiscale geometric information. This allows for a more faithful and efficient simulation of reality that can adapt to differing speed and resolution criteria. The computation time of the algorithm is tested against other established solvers by solving sample PDEs to a target accuracy. Experimental results show that the developed algorithm is faster than many standard methods, and competitive with the fastest of them, indicating it is highly computationally efficient. The algorithm also provides increased flexibility due to its adaptive multilevel structure, enabling faster generation of computer simulations of reality, thereby making it possible to model large-scale real-world problems.

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