SkewEngine: Enhancing Performance of Intensive Calculations on Regular Mesh Data

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Abstract

In various applications such as hyperspectral data manipulation, MRI data exploration, or visual basin identification in digital elevation models, performing arithmetic operations on each point of a data mesh that involve other points can lead to computationally intractable problems. This paper presents SkewEngine, a tool designed to improve the performance of intensive calculations on regular 2D or 3D data meshes, such as images, multispectral data volumes, or digital elevation models. SkewEngine addresses this problem by reorganizing the mesh in memory according to a preferred spatial direction, enabling more efficient execution of intensive calculations. It is demonstrated that SkewEngine offers significant speed improvements for a variety of test cases, suggesting its usefulness in a broader range of applications requiring intensive data processing on regular meshes.

In scenarios where the calculation of visual basins is not limited to a single observer's viewpoint but needs to consider arbitrary paths or regions in the terrain, the computational complexity can increase significantly, reaching $O(N^2.5)$. Even with lower precision, simple models can take months of CPU time to calculate. However, such problems fall into a category where the study parameters decay based on geometric distance within the data mesh, often following a quadratic pattern. Exploiting this characteristic, these problems are typically simplified by processing data in a discrete set of radial directions with respect to a study point, as the radii are closer to the point of origin, resulting in a finer mesh at the study point. However, in problems where spatial locality is critical, there is a need to transfer this spatial locality to the data itself, particularly in terms of memory storage. Consider an example where a filter needs to be applied to an image in all directions parallel to a specific arrow. It is evident that any computationally intensive algorithm like FFT would be more efficient if the data were aligned in memory, as shown in the deformed image on the right side of Figure 1.

This work proposes to analyze and exploit the benefits of memory reorganization, specifically demonstrating the significant benefits of biased data interpolation in highly complex problems.

Background: The SDEM Algorithm

In 2013, Tabik et al. [2] proposed an algorithm that considered radial dependence in visual basin calculation, reducing the complexity from $O(N^{2.5})$ to $O(sN^{1.5})$ by considering a

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