Walk on Spheres / Stars on WebGPU

Introduction

References:

- Walk On Spheres (original method)
- Walk On Stars Neumann Boundary Conditions
- Walkin' Robin: Walk on Stars with Robin Boundary Conditions

Modern electronics are limited by heat dissipation. Being able to quickly visualize and simulate heat diffusion across circuit boards is critical during early prototyping, yet most PCB design tools provide little to no thermal feedback. Full finite-element solvers are accurate but slow. Doing a global, high-fidelity solve is often overkill and requires a full re-simulation every time a small change is made. This project targets that bottleneck by introducing a browser-based GPU thermal estimator built on the Walk-on-Spheres (WoS) algorithm. WoS allows for fast re-simulation on geometry changes, localized solves over targeted regions, and a progressive convergence that provides immediate, intermediate estimates. All of these are advantageous for quick design iteration and prototyping.

WoS works by launching random walks from query points until they hit a boundary. Drawing inspiration from path tracing and sphere tracing, each walk contributes to a Monte Carlo estimator that converges toward the true solution of the steady-state heat equation. Because each walk is independent, the method is embarrassingly parallel, making it a perfect fit for WebGPU compute shaders.

The tool will allow users to import or draw PCB layouts, assign material properties (FR-4, copper, components), set boundary conditions and heat sources, and interactively move components while the heat distribution updates in real time. The system aims to provide meaningful thermal insight early in the design process helping users catch potential hotspots and understand how layout changes affect cooling without needing the overhead of traditional FEA workflows.

Implementation & Schedule

Language: TypeScript
Libraries: WebGPU, TinyOBJ, SVG/JSON parsing for PCB geometry import
Milestone 1: project framework, user interaction / test geometry, WoS started
Milestone 2: WoS / WoSt solvers
Milestone 3: PCB importing and solver
Final: Working simulation and interactive tool, report and analysis (comparisons, future work)