Extreme Scale FMM-Accelerated Boundary Integral Equation Solver for Wave Scattering: Supplementary Material

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BEMFMM (https://ecrc.github.io/BEMFMM/) is an extreme-scale Fast Multipole Method (FMM)-accelerated Boundary Element Method (BEM) parallel solver framework. It is a boundary integral equation solver for wave scattering suited for many-core processors, which are expected to be the building blocks of energy-austere exascale systems, and on which algorithmic and architecture-oriented optimizations are essential for achieving worthy performance. It uses the GMRES iterative method and FMM to implement the MatVec kernel. The underlying kernels are highly optimized for both shared- and distributed-memory architectures. The solver framework features optimal architecture-specific and algorithm-aware partitioning, load balancing, and communication reducing mechanisms. To this end, BEMFMM framework provides a highly scalable FMM implementation that can be efficiently applied to the computation of the Helmholtz integral equation kernel. In particular, it deals with addressing the parallel challenges of such application, especially at extreme-scale settings, with emphasis on both shared- and distributed-memory performance optimization and tuning on emerging HPC infrastructures.

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1. INTRODUCTION

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Naming Convention for Countable Items

Algorithm S1
Equation (S1)
Figure S1

Media S1
Table S1

3. EXAMPLES OF SUPPLEMENTARY MATERIAL COMPONENTS

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A. Sample Figure

Figure S1 shows an example figure.

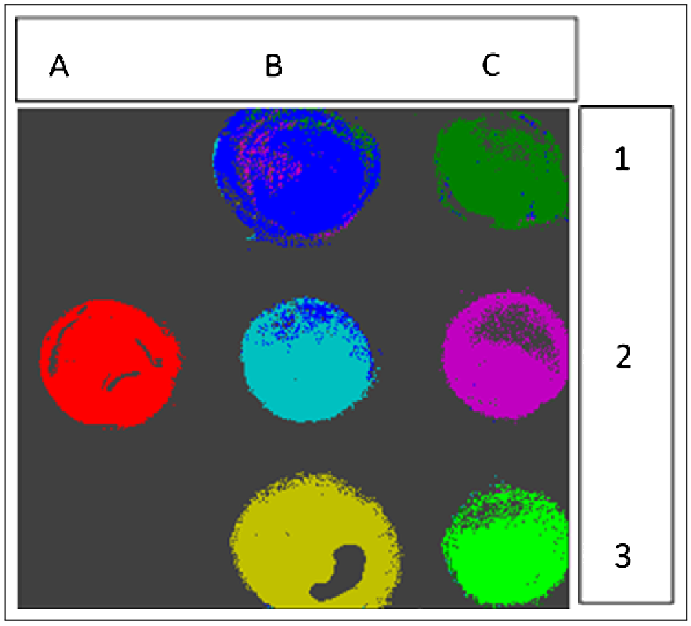

Fig. S1. False-color image, where each pixel is assigned to one of seven reference spectra.

B. Sample Table

Table S1 shows an example table.

Table S1. Shape Functions for Quadratic Line Elements

local node	$\{N\}_m$	$\{\Phi_i\}_m$ $(i = x, y, z)$
$m = 1$	$L_1(2L_1 - 1)$	Φ_{i1}
$m = 2$	$L_2(2L_2 - 1)$	Φ_{i2}
$m = 3$	$L_3 = 4L_1L_2$	Φ_{i3}

5. SAMPLE EQUATION

Let $X_1, X_2, \ldots, X_n$ be a sequence of independent and identically distributed random variables with $\mathrm{E}[X_i] = \mu$ and $\mathrm{Var}[X_i] = \sigma^2 < \infty$, and let

$$S_n = \frac{X_1 + X_2 + \cdots + X_n}{n} = \frac{1}{n}\sum_{i}^{n} X_i \qquad \text{(S1)}$$

denote their mean. Then as n approaches infinity, the random variables $\sqrt{n}(S_n - \mu)$ converge in distribution to a normal $\mathcal{N}(0, \sigma^2)$.

6. SAMPLE ALGORITHM

Algorithms can be included using the commands as shown in algorithm S1.

Algorithm S1. Euclid's algorithm

```
1: procedure EUCLID(a, b)          ▷ The g.c.d. of a and b
2:     r ← a mod b
3:     while r ≠ 0 do              ▷ We have the answer if r is 0
4:         a ← b
5:         b ← r
6:         r ← a mod b
7:     return b                    ▷ The gcd is b
```

MEDIA

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REFERENCES

1. Y. Zhang, S. Qiao, L. Sun, Q. W. Shi, W. Huang, L. Li, and Z. Yang, "Photoinduced active terahertz metamaterials with nanostructured vanadium dioxide film deposited by sol-gel method," Opt. Express **22**, 11070–11078 (2014).