Verification of water droplet transport in the Fire Dynamics Simulator

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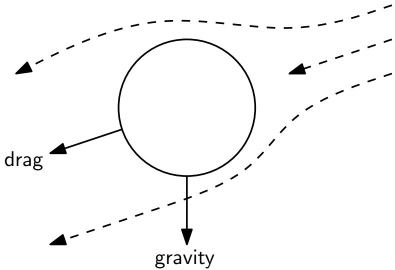
Lagrangian particles from a sprinkler

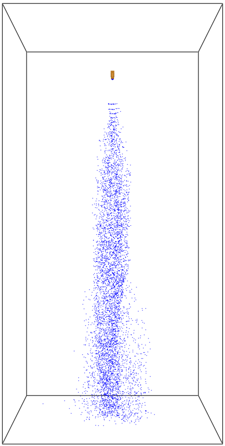
Particle drag model basics

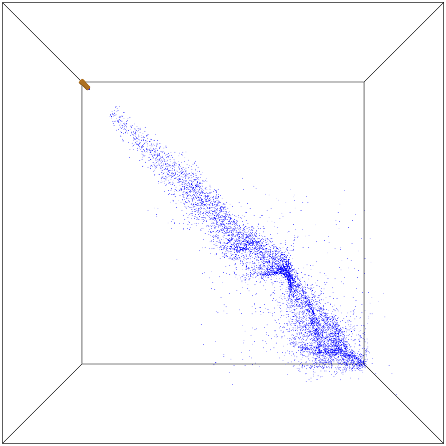


$$m_p \frac{\mathrm{d}\mathbf{u}_p}{\mathrm{d}t} = \underbrace{-\tfrac{1}{2}\rho_\mathrm{a} C_{\mathrm{d},p} A_p (\mathbf{u}_p - \mathbf{U}_p)||\mathbf{u}_p - \mathbf{U}_p||}_{\text{drag}} + \underbrace{m_p \mathbf{g}}_{\text{gravity}}$$

$$\frac{\partial \mathbf{U}}{\partial t} - \mathbf{U} \times \omega + \nabla \mathcal{H} - \tilde{p}\,\nabla\left(\frac{1}{\rho}\right) = \frac{1}{\rho}\Big[(\rho - \rho_0)\mathbf{g} + \underbrace{\mathbf{f}_\mathrm{b}}_{\substack{\text{drag force}\\ \text{per volume}}} + \nabla \cdot \tau\Big]$$

Solution is not independent of the angle of the spray with the grid





A Stochastic Performance Model for Pipelined Krylov Methods

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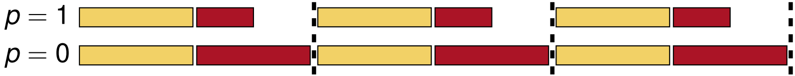
In a simple deterministic setting, during each iteration k of a Krylov method, each process takes a certain time c_p for local computation (yellow below) and w_p for waiting (red) so that the total running time is $T = \sum_k \max_p (c_p + w_p)$.



If we remove the synchronizations, the total running time is given by $T' = \max_p \sum_k (c_p + w_p)$ so that no speedup is achieved.

$$\text{speedup} = \frac{T}{T'} = \frac{\sum_k \max_p (c_p + w_p)}{\max_p \sum_k (c_p + w_p)} = 1$$

Instead, let T_p^k be a stochastic process time for process p and step k drawn from some distribution. The total time of a Krylov algorithm with synchronizations is given by $T = \sum_k \max_p T_p^k$ and the total time for the pipelined version is $T' = \max_p \sum_k T_p^k$.

$$\text{speedup} = \frac{E[T]}{E[T']} = \frac{\sum_k E[\max_p T_p^k]}{E[\max_p \sum_k T_p^k]} \approx \frac{E[\max_p T_p^k]}{\mu}$$

$\frac{E[T]}{E[T']}$ has an integral representation and we can compute it for common distributions.

uniform distribution: $\frac{E[T]}{E[T']} = \frac{2P}{P+1} < 2$ for all P

exponential distribution: $\frac{E[T]}{E[T']} > 2$ for all $P \geq 4$

To show that our stochastic model is a reasonable, we fit observed PGMRES (left) and PIPECG (right) runtimes to some underlying distributions.