Population Control Technique Exploration in MC/DC

Ilham Variansyah, Ryan G. McClarren
Center for Exascale Monte-Carlo Neutron Transport (CEMeNT), University of Notre Dame

Objective

To review, implement parallel algorithms, and assess performances of PCTs.

Population Control Technique (PCT)

Initial population
- Size N
- Total weight W
- $C_i = w_i,\ i \in [1, N]$

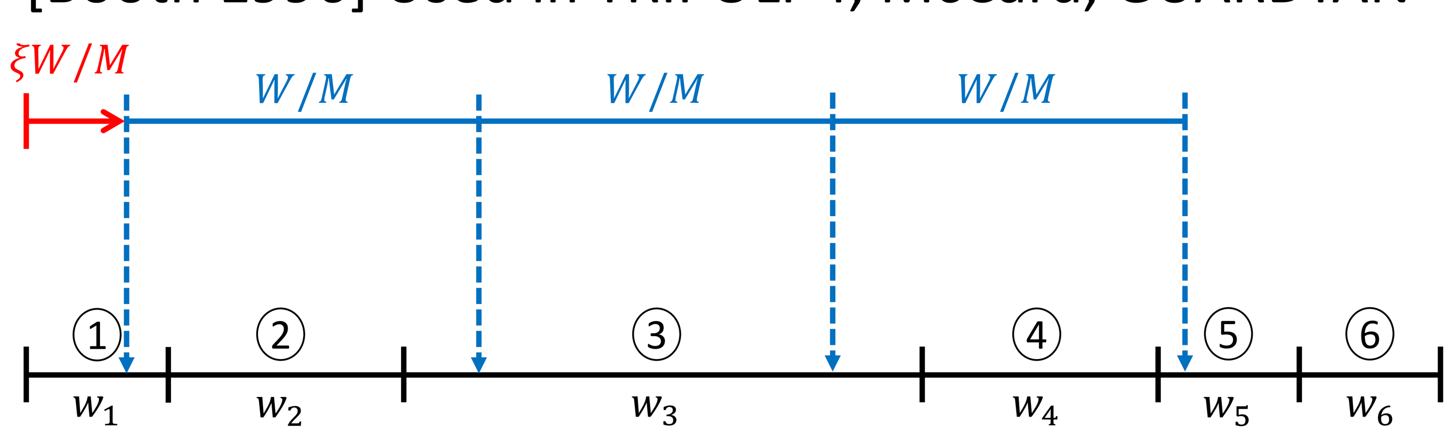
PCT →

Final population
(1) Size $\sim M$
(2) $\mathbf{E}[C_i] = w_i$
(3) Low $\mathbf{Var}[C_i]$
(4) Total weight $\sim W$

Five Identified PCTs

Combing (CO)

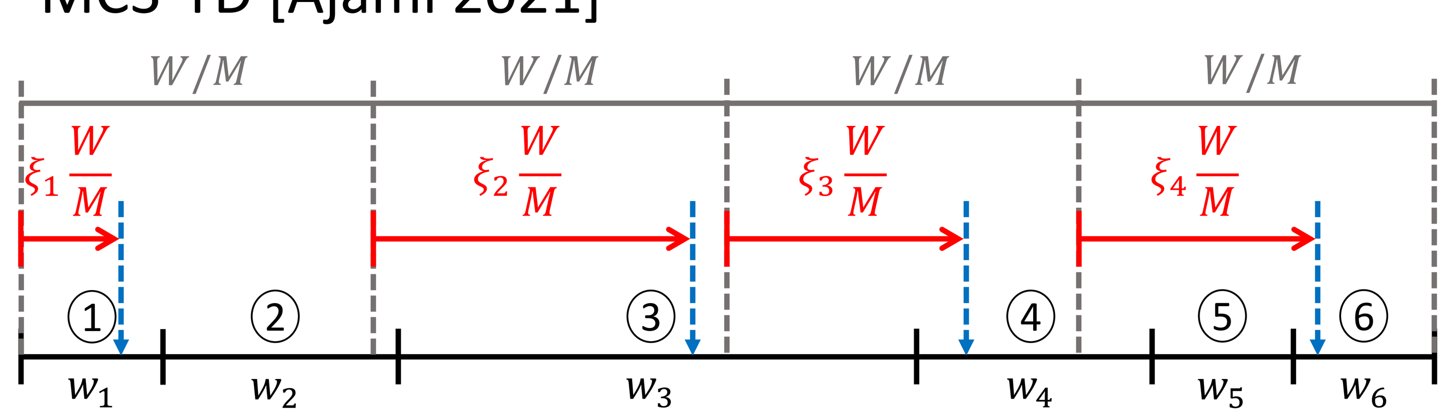
[Booth 1996] Used in TRIPOLI-4, McCard, GUARDYAN



Possible unwanted behavior due to correlation

New Combing (COX)

MC3-TD [Ajami 2021]

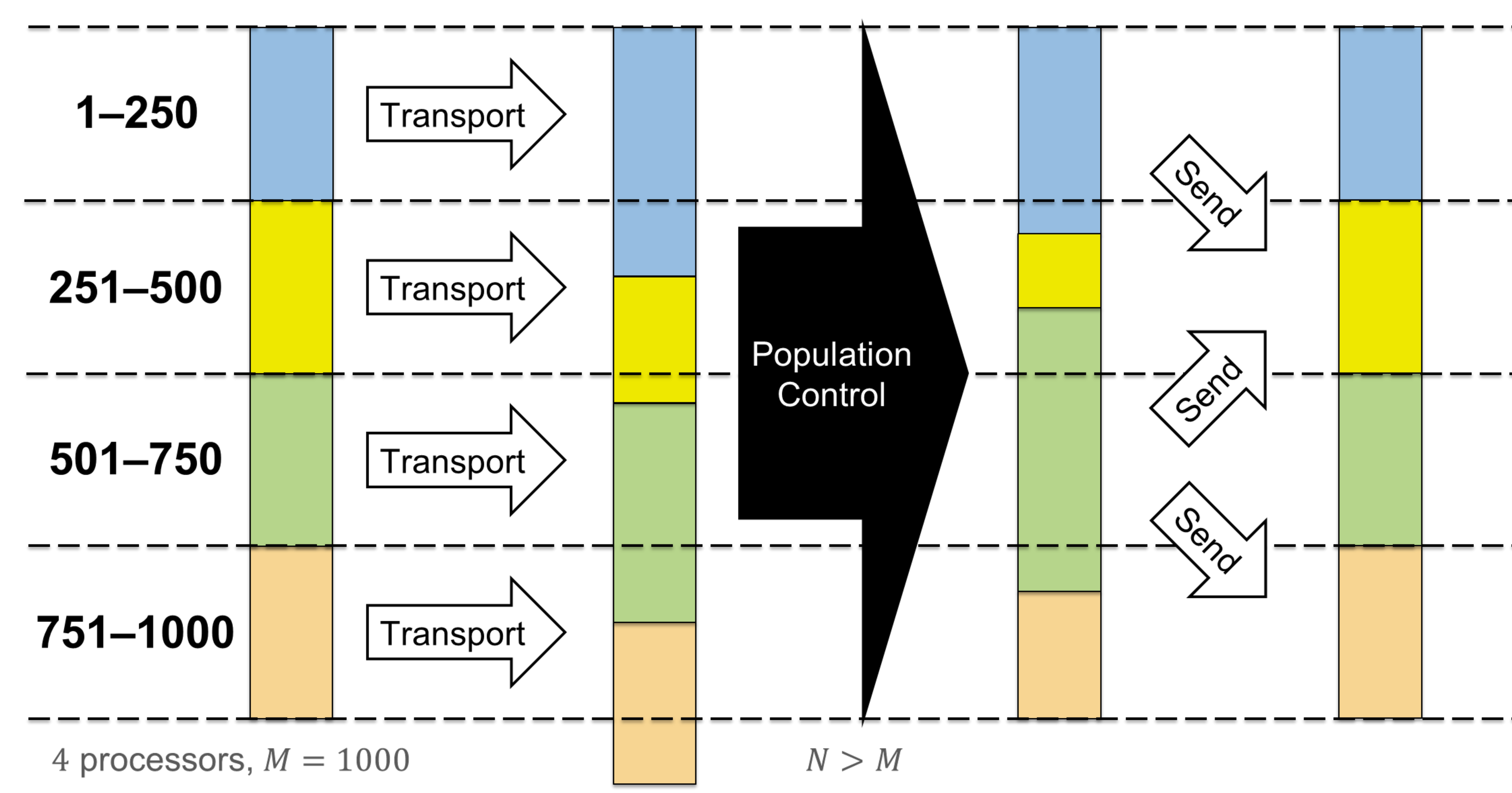


Avoid the unwanted behavior of CO

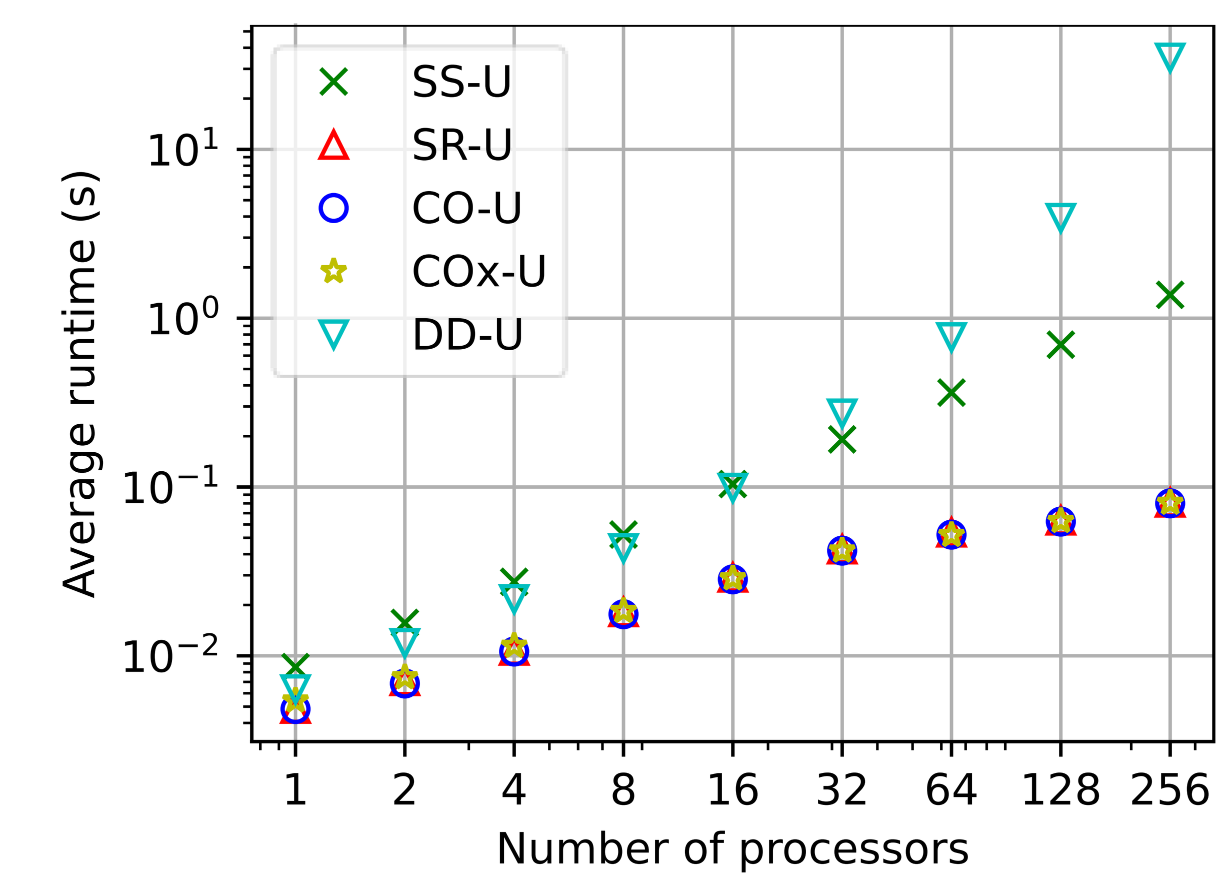
Splitting-Roulette (SR)

Used in MCATK [Sweezy 2014]
(1) Assign each particle i with $p_i = w_i/(W/M)$
(2) Split into $\lfloor p_i \rfloor + 1$ copies
(3) Roulette the last one (surviving probability $\lfloor p_i \rfloor - p_i$)
Does not exactly yield M particles or preserve W

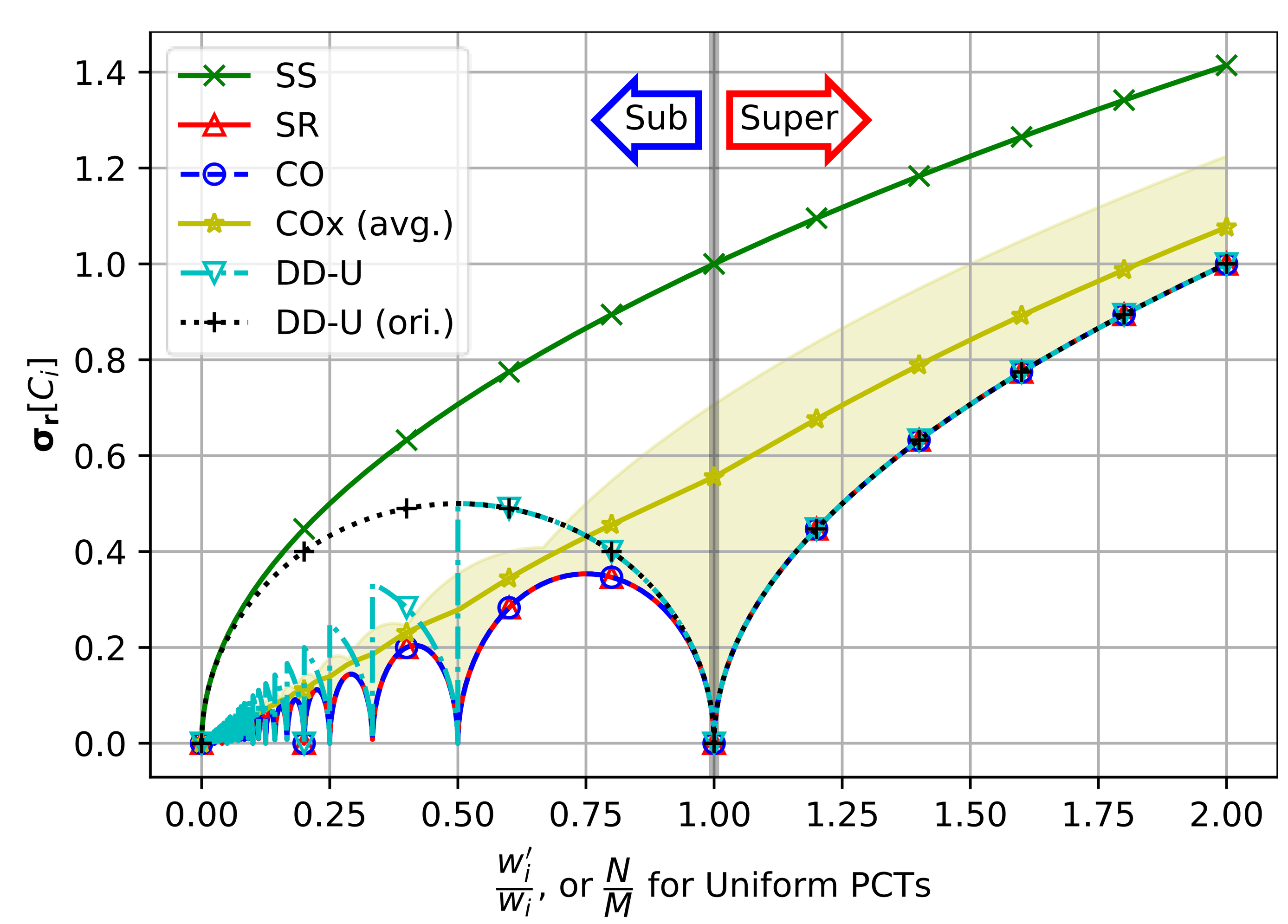
Parallel PCT Algorithm (adapted from [Romano 2012])



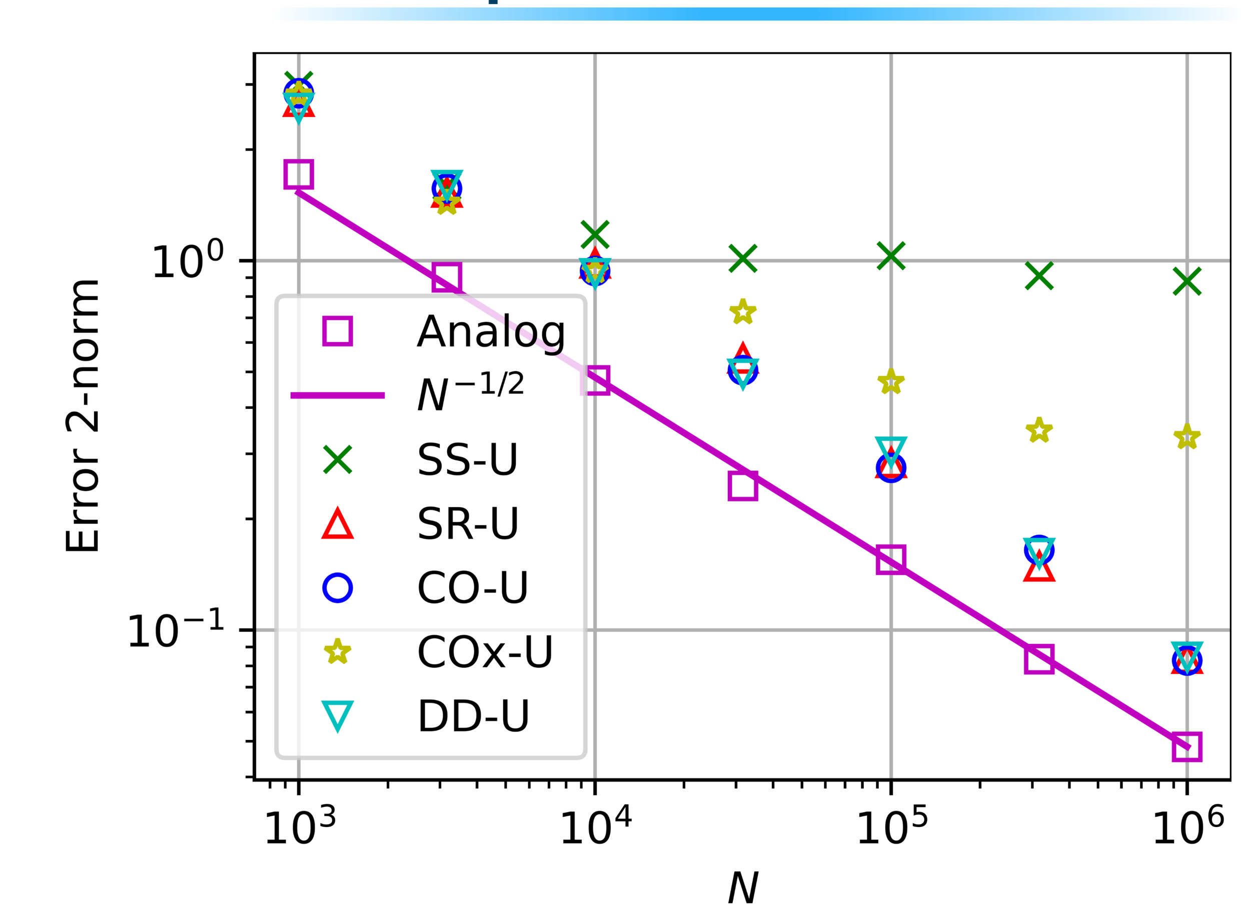
Weak Scaling (Quartz)



Relative Uncertainty Introduced by the PCTs



Supercritical AZUREV1



Duplicate-Discard (DD)

Used in Serpent 2 [Leppänen 2013]
- If $M < N$, duplicate $N - M$ particles
- Otherwise, discard $M - N$ particles

Simple Sampling (SS)

Used in eigenvalue simulations (fission-census)
TD application demonstrated by [Nauchi 2019]
- Sample M particles from initial population

Key Takeaways

- **Common algorithm for parallel PCT on time-dependent (time-census) and eigenvalue (fission-census) simulations**
- **Scalability: (best) CO, SR, and COX | (worst) SS and DD**
- **Variance introduced: (best) CO and SR | (worst) SS**
- **SR does not exactly yield size of M or preserve W**
- **CO may produce unwanted behavior due to correlation in initial particle order.**
- **COX avoids possible unwanted behavior of CO at the expense of increased variance.**