Final Projects

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General Guidelines and Requirements

1. Must parallelize your program by at least one of the following methods
   a. OpenMP (minimum requirement)
   b. MPI (get bonus point)
   c. GPU (get extra bonus point)

2. Must provide convincing demonstration of the accuracy and performance of your program

3. Must use GitHub for collaborative development
   a. Tutorial: https://guides.github.com
   b. Use the Fork→Pull→Push→Pull Request→Merge workflow
   c. Do NOT just upload the final code → must keep the development history on GitHub

4. Students per group: 2~3 (two groups with 2 students and five groups with 3 students)
   a. Inform the TA before May 5

5. Final presentation: June 16 and 23
   a. 25 mins presentation + 5 mins questions
   b. All students are encouraged to ask ANY questions

6. Bonus points: *Surprise Me!!!*

Project-I: High-order Data Reconstruction in Hydro

1. **Implement at least one of the following data reconstruction methods**
   a. **Piecewise Parabolic Method (PPM)**
      https://www.sciencedirect.com/science/article/pii/0021999184901438
   b. **Piecewise Cubic Method (PCM)**
      https://www.sciencedirect.com/science/article/pii/S0021999117302759?via%3Dihub
   c. **Weighted Essentially Non-Oscillatory (WENO)**
      https://www.sciencedirect.com/science/article/pii/S0021999116301371
   d. **Gaussian Process (GP)**
      https://link.springer.com/article/10.1007/s10915-017-0625-2
      https://www.sciencedirect.com/science/article/pii/S0021999119300099
2. **Compare the accuracy and performance with PLM**
3. **Bonus points**
   a. **Implement the *characteristic tracing* step (described in some of these schemes, e.g., PPM & PCM) to improve the temporal resolution**
   b. **Extend to *2D or even 3D***
   c. **MHD**
   d. **Add self-gravity**

Project-II: Multigrid Poisson Solver

1. **Implement the multigrid method to solve the 2D Poisson equation**
   a. **Compare the V and W cycles**
   b. **Measure the performance scaling (i.e., wall-clock time vs. number of cells)**
   c. **Compare the performance with SOR**

2. **Bonus points**
   a. **Implement the *full multigrid method* (FMG) and compare with MG**

3. **Reference**
   a. **Enzo:** https://github.com/enzo-project/enzo-dev/blob/master/src/enzo/MultigridSolver.C
   b. **GAMER:** https://github.com/gamer-project/gamer/blob/master/src/SelfGravity/CPU_Poisson/CPU_PoissonSolver_MG.cpp
   c. **Numerical Recipes, Chapter 20.6**
   d. **Multigrid Techniques: 1984 Guide with Applications to Fluid Dynamics** https://epubs.siam.org/doi/book/10.1137/1.9781611970753

Project-III: Conjugate Gradient Poisson Solver

1. Implement the conjugate gradient method (CG) to solve the 2D Poisson equation
   a. Measure the performance scaling (i.e., wall-clock time vs. number of cells)
   b. Compare the performance with SOR
2. Bonus points
   a. You get bonus points automatically since CG is not covered by this lecture

Project-IV: Particle Mesh

1. **Implement the particle mesh scheme in 3D**
   a. **Poisson solver: periodic with FFT**
   b. **Mass deposition: NGP, CIC, and TSC → compare their accuracy**
   c. **Orbit integration: KDK and DKD → compare their accuracy**
   d. **Measure the performance scaling (i.e., wall-clock time vs. number of cells/particles)**
   e. **Validate the momentum conservation**

2. **Bonus points**
   a. **Implement the *isolated boundary condition* for the Poisson solver**
   b. **Implement the *RK4 and/or Hermite* scheme for orbit integration**
   c. **Individual time-step integration (see the reference of Hermite integration below)**

3. **Reference**
   a. **Computer Simulation Using Particles by Hockney and Eastwood:** https://www.amazon.com/Computer-Simulation-Using-Particles-Hockney/dp/0852743920
   b. **Hermite integration:** http://articles.adsabs.harvard.edu//full/1992PASJ...44..141M/0000141.000.html

Project-X

1. YOU DECIDE!!
   a. Must still follow the “General Guidelines and Requirements”
   b. Must discuss with me before May 12
   c. Better not to be directly related to your thesis (but reach me if you have a good idea!)

2. Bonus points
   a. Apply to a real problem