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Notes:

- You have two weeks to work on this exercise.

Exercise 1 *Parallel Implementation of the Astrophysical N-body Problem*

In this exercise we will work with the n-body program from the `hasc-code` repository. The following is an overview of the files that we are intereseted:

Strategy	Data Layout	Instruction Set	File
Flat/Blocked	AoS	-	`nbody_vanilla.cc`
Blocked	AoS	AVX2	`nbody_avx.cc`
Blocked	AoS	NEON	`nbody_neon.cc`
Blocked	SoA	SSE2/AVX2/AVX512	`nbody_intel_SoA.cc`

1. Get the code, familiarize yourself with the it and run some simple simulations on `nbody_vanilla.cc`.
2. Install paraview[2] and visualize the results.
3. Check if the implementation does conserve the energy of the system. The total energy $E_{total}(t)$ is the sum of the potential energy and the kinetic energy:

$$E_{total}(t) = E_{pot}(t) + E_{kin}(t)$$

$$E_{pot}(t) = -\frac{1}{2}\gamma \sum_{j=0}^{n-1} \sum_{i \neq j} \frac{m_i m_j}{\|x_j - x_i\|}$$

$$E_{kin}(t) = \frac{1}{2} \sum_{i=0}^{n-1} m_i \|v_i(t)\|^2$$

   Plot total energy over time and check if the total energy stays (roughly) constant.

4. On all the versions available for your architecture, get yourself familiar with the vectorized versions and run perforamnce measurments
   - In the case of AoS version in `nbody_intel_SoA.cc`, be sure to investigate the different vector widths with the `simd_width` template argument of the function.
   - Be sure to execute with `export OMP_NUM_THREADS=1` enviromental variable to run the code in one thread.
5. Try to implement this problem in a faster way. You can try whatever you want. Explain your reasoning.
   Hint: We suggest to compute the interactions of $w \times w$ masses in the inner-most loop where w is your SIMD width.

(1+0+4+4+9 Points)

[2] `https://www.paraview.org/`