Advanced Optimization Techniques

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Compiler Pragmas and Array Notations

Exercises

Problem 1 - Wave Equation (easy)

- Consider a 1D acoustic wave equation

$$\frac{\partial^2 \varphi}{\partial^2 t} = c^2 \frac{\partial^2 \varphi}{\partial^2 x} \Rightarrow \frac{\varphi_x^{t+1} + \varphi_x^{t-1} - 2\varphi_x^t}{(\Delta t)^2} = c^2 \frac{\varphi_{x+1}^t + \varphi_{x-1}^t - 2\varphi_x^t}{(\Delta x)^2}$$

$$\varphi_x^{t+1} = c^2 \underbrace{\frac{(\Delta t)^2}{(\Delta x)^2}}_{a} \left(\varphi_{x+1}^t + \varphi_{x-1}^t\right) + \underbrace{2\left(1 - c^2 \frac{(\Delta t)^2}{(\Delta x)^2}\right)}_{b} \varphi_x^t - \varphi_x^{t-1}$$

$$\varphi_x^{t+1} = a\left(\varphi_{x+1}^t + \varphi_{x-1}^t\right) - b\,\varphi_x^t - \varphi_x^{t-1}$$

Problem 1 - Wave Equation (easy)

- A serial version (standard C) of this problem is supplied
- Write this code in Array Notations
- Are you faster than the original (you are not supposed to :-))
- Where do you think the difference comes from?

Problem 2 - Wave Equation (medium)

- Very often, a second order finite difference stencil is insufficient
- Let us consider forth order approximation:

$$\frac{\partial^2 \varphi}{\partial x^2} \approx \frac{-\varphi_{i-2} + 16\varphi_{i-1} - 30\varphi_i + 16\varphi_{i+1} - \varphi_{i+2}}{12(\Delta x)^2}$$

- Extend the C and Array Notations code to use the forth order spatial derivative
- Compare the compiler and explicit performance

Problem 3 - Matrix multiplication (medium)

- Consider a 4x4 matrix multiplication

  $$\boldsymbol{C} = \boldsymbol{C} + \boldsymbol{A} \cdot \boldsymbol{B}$$

  for a large number of matrices
- Code doing this using a standard BLAS routine (DGEMM) is supplied
- Write the matrix multiplication in normal C
- Use compiler pragmas to improve the vectorization (also think about manual unroll or using pragma unroll)
- Use Array Notations to achieve the same