Announcements

- Assignment 2 is due on Oct 19
- Midterm on Oct 27
- Interim report due on November 16
Group project

• Check your email for project feedback

• Reply to email if you want to discuss further

• Peer evaluation: you are given $100 that you will allocate as a performance bonus to your group members based on your assessment of their contributions to the project (you cannot keep any money for yourself)
Matrix multiplication

for (i=0; i<M; i++)
for (j=0; j<N; j++)
for (k=0; k<L; k++)
    C[i][j] += A[i][k]*B[k][j];

https://en.wikipedia.org/wiki/Matrix_multiplication
Matrix multiplication

```c
for (i=0; i<M; i++)
    for (j=0; j<N; j++)
    for (k=0; k<L; k++)
        C[i][j] += A[i][k]*B[k][j];
```

Any performance issues for large arrays?

https://en.wikipedia.org/wiki/Matrix_multiplication
Blocking to improve cache performance

- Create smaller blocks that fit in cache: leads to cache reuse
- \( C_{12} = A_{10} \times B_{02} + A_{11} \times B_{12} + A_{12} \times B_{22} + A_{13} \times B_{32} \)
Parallel matrix multiply

- Store A and B in a distributed manner
- Communication between processes to get the right sub-matrices to each process
- Each process computes a portion of C
Cannon’s 2D matrix multiply

\[
\begin{array}{cccc}
0 & 1 & 2 & 3 \\
4 & 5 & 6 & 7 \\
8 & 9 & 10 & 11 \\
12 & 13 & 14 & 15 \\
\end{array}
\]

\[
\begin{array}{cccc}
A_{00} & A_{01} & A_{02} & A_{03} \\
A_{10} & A_{11} & A_{12} & A_{13} \\
A_{20} & A_{21} & A_{22} & A_{23} \\
A_{30} & A_{31} & A_{32} & A_{33} \\
\end{array}
\]

\[
\begin{array}{cccc}
B_{00} & B_{01} & B_{02} & B_{03} \\
B_{10} & B_{11} & B_{12} & B_{13} \\
B_{20} & B_{21} & B_{22} & B_{23} \\
B_{30} & B_{31} & B_{32} & B_{33} \\
\end{array}
\]
Cannon’s 2D matrix multiply

Initial skew
Cannon’s 2D matrix multiply

Initial skew
Cannon’s 2D matrix multiply

Shift-by-1
Agarwal’s 3D matrix multiply

- Copy A to all i-k planes and B to all j-k planes
Agarwal’s 3D matrix multiply

- Perform a single matrix multiply to calculate partial C
- All-to-all along i-j planes to calculate final result