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Performance Experiments
with Matrix Multiplication

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Hardware: 2.66GHz Intel Core 2 Duo
64-bit mode, double precision, gcc 4.1.2

optimized BLAS dgemm: ATLAS 3.6.0

http://math-atlas.sourceforge.net
A trivial problem?

\[ C = A \ B \]

\[ m \times p \quad m \times n \quad n \times p \]

the “obvious” C code:

```c
/* C = A B, where A is m x n, B is n x p, 
and C is m x p, in row-major order */
void matmul(const double *A, const double *B, 
double *C, int m, int n, int p)
{
    int i, j, k;
    for (i = 0; i < m; ++i) 
        for (j = 0; j < p; ++j) {
            double sum = 0;
            for (k = 0; k < n; ++k)
                sum += A[i*n + k] * B[k*p + j];
            C[i*p + j] = sum;
        }
}
```

just three loops, how complicated can it get?

\[
C_{ij} = \sum_{k=1}^{n} A_{ik}B_{kj}
\]

for \( i = 1 \) to \( m \)

for \( j = 1 \) to \( p \)

\( 2mnp \) flops

(adds+mults)
flops/time is not constant!
(square matrices, $m=n=p$)

(2.66GHz processor? why < 1 gigaflops?)
Not all “noise” is random
All flops are not created equal

same #operations
same abstract algorithm
factor of 10 in speed

nearly peak theoretical flop rate
(2 flops/cycle via SSE2 instructions)
Things to remember

- We cannot understand performance without understanding memory efficiency (caches).
  - ~10 times more important than arithmetic count
- Computers are more complicated than you think.
- Even a trivial algorithm is nontrivial to implement well.
  - matrix multiplication: 10 lines of code → 130,000+ (ATLAS)