

# CS 5220

## Project 1 - Matrix Multiplication

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### 1 Overview

In this project, we tried several methods to fine-tune square matrix multiplication. Based on the `dgemm_blocked.c`, we tried unrolling inner loop multiplication, modifying loop sequence to take advantage of SSE, experimenting with different optimization flags, multiple blocks sizes and copy optimizations.

The next section reflects our various optimization attempts and their results.

### 2 Optimization Attempts

#### 2.1 Block Multiplication with Multiple Block Sizes

##### 2.1.1 Approach

Working off of `dgemm_blocked.c`, we tried different block sizes to examine the performance changes.

##### 2.1.2 Results

Figure 1 shows the performance of different approaches with various block sizes. (block sizes are a multiple of 2). The performance gain for varying block sizes is not immense but a block size of 64 performs better than other block sizes.

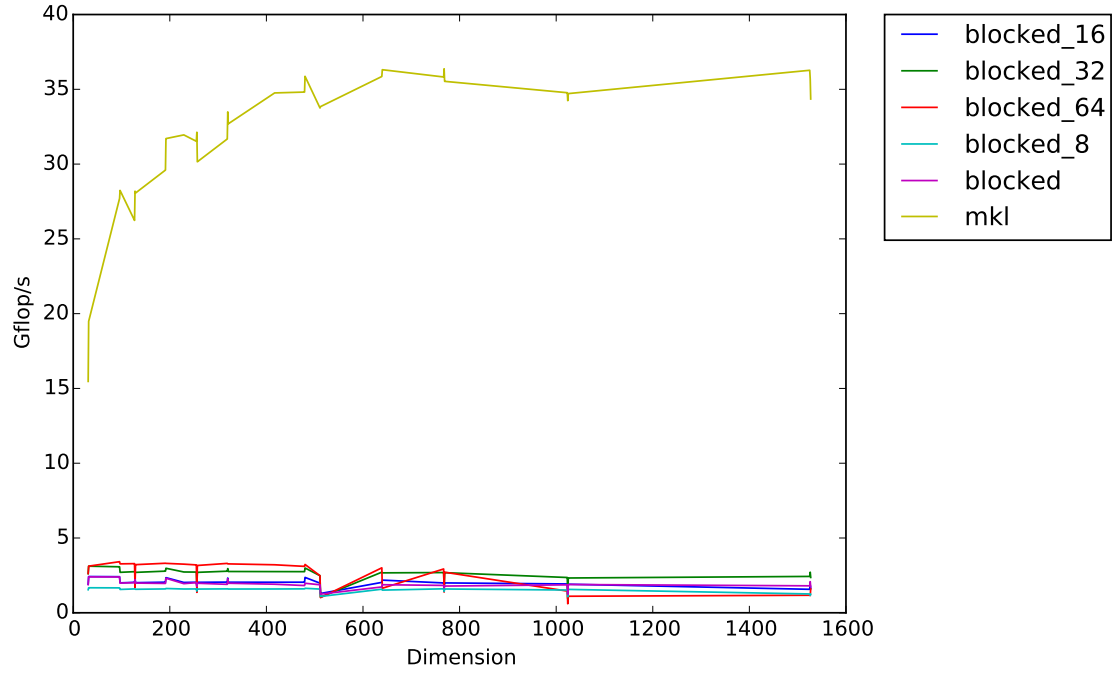


Figure 1: Block size variation

In addition, we attempted block sizes that are not a multiple of 2. Figure 2 is the comparison of the performance against a block size of 64.

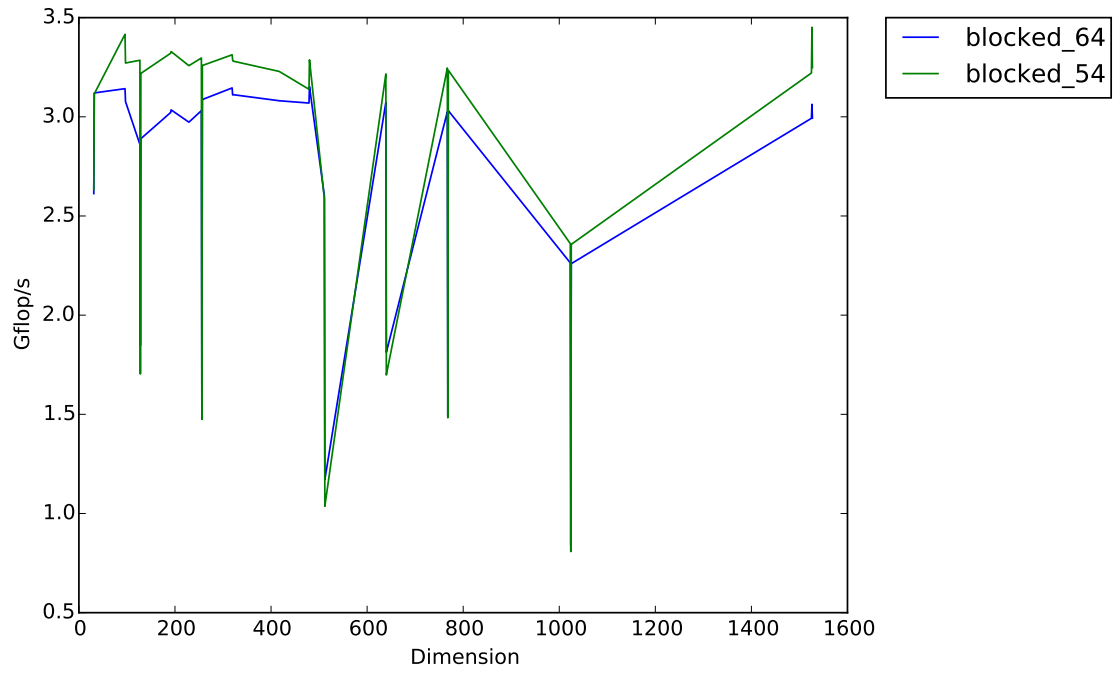


Figure 2: Block size variation

## 2.2 Block Multiplication with Manual Loop Unrolling

### 2.2.1 Approach

In this approach, we manually unrolled 4 computations in the inner most loop of the matrix multiplication of a block.

### 2.2.2 Results

Figure 3 compares the performance of the unrolled blocked version against the vanilla blocked approach. The unrolled versions clearly perform better than the original blocked approach but not by much.

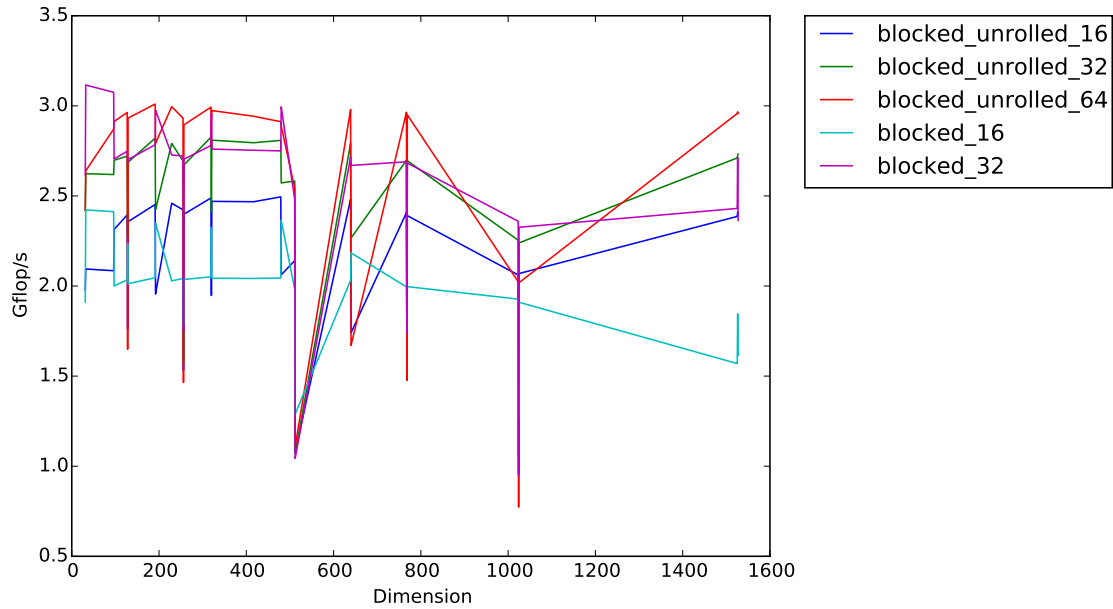


Figure 3: Unrolled blocks vs regular blocks

## 2.3 Compiler Optimization Flags

### 2.3.1 Approach

Using the blocked approach as a baseline, we examine the effect of various compiler flags on the multiplication.

### 2.3.2 Results

Figure 4 shows the performance of blocked multiplication with the flags, `-O3 -march=native -funroll-loops`.

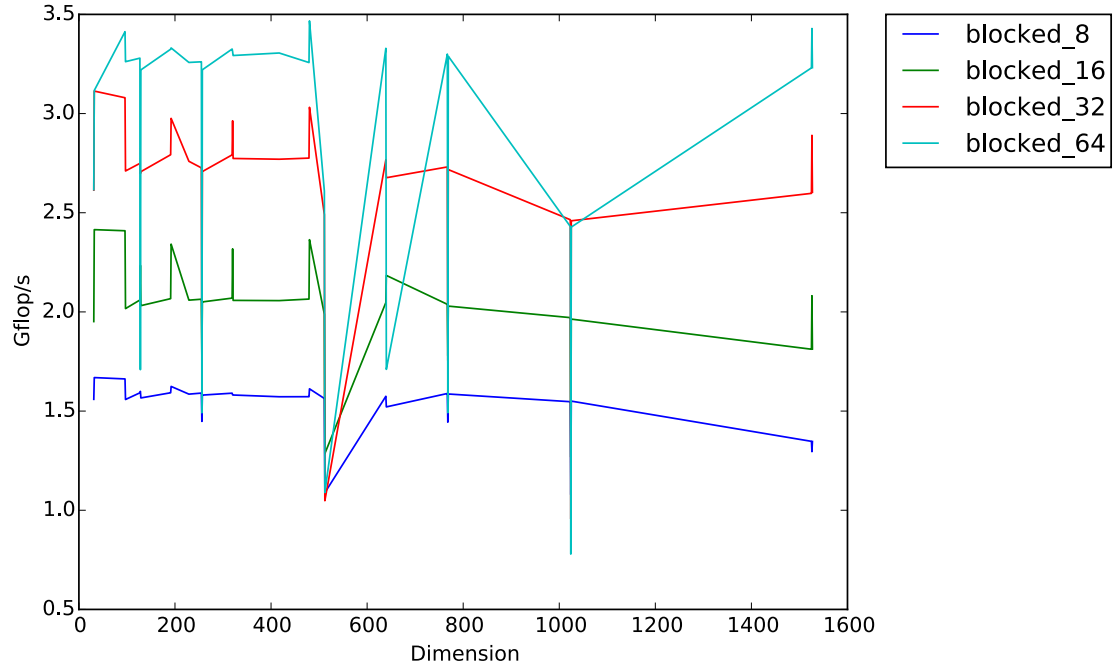


Figure 4: Compiler flags `-O3 -march=native -funroll-loops`

Figure 5 shows the performance of blocked multiplication with the flags, `-O3 -funroll-loops` vs just `-O3`. It appears that merely having the `-O3` flag performs as well as having loops unrolled.

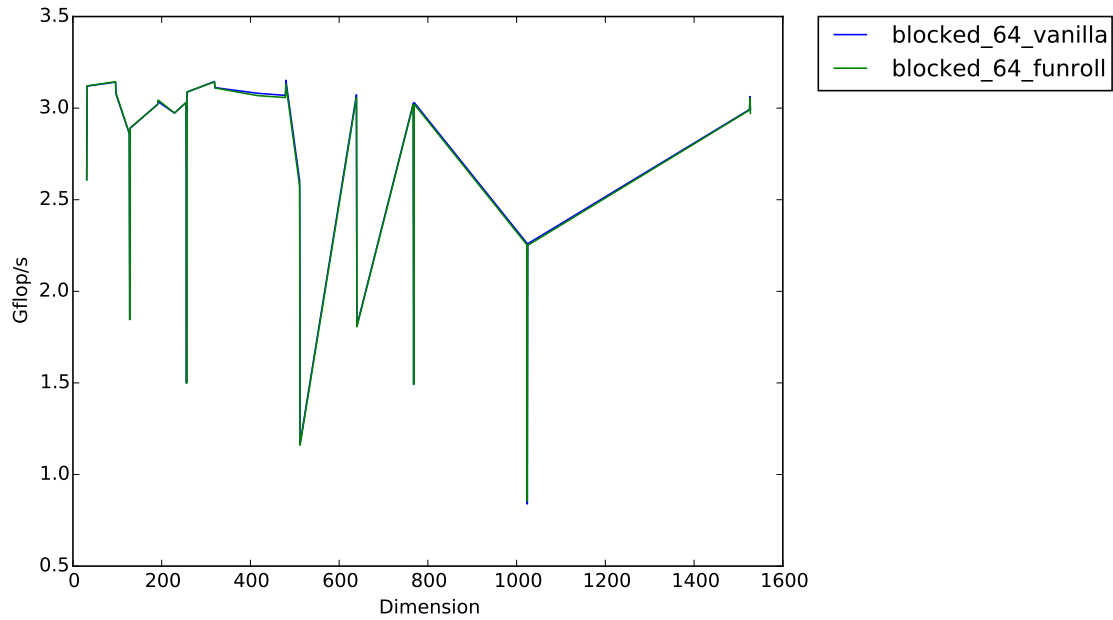


Figure 5: Compiler flags `-O3 -funroll-loops`

## 2.4 Loop reordering

### 2.4.1 Approach

The current block multiplication in the innermost loop does not have unit stride with  $i, j, k$  loop ordering.

### 2.4.2 Results

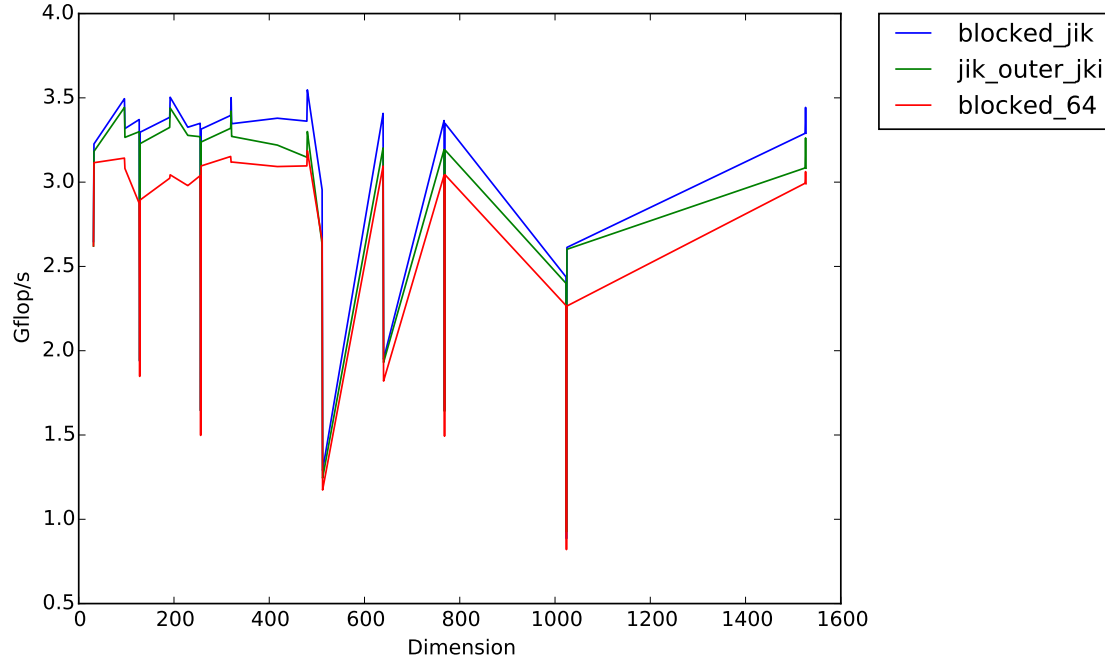


Figure 6: Loop reordering ijk vs jik vs jik and outer loop jki

## 2.5 Copy Optimization

### 2.5.1 Approach

In the basic version of dgemm, we see drops near matrix sizes that are a multiple of 2. This is caused by conflict misses due to associative caches. To prevent this, we attempted a copy optimization over the basic dgemm implementation.

### 2.5.2 Results

There is a clear improvement in performance and the conflict misses are converted to gains in performance as seen in Figure 7. Copy optimization is clearly a step in the right direction.

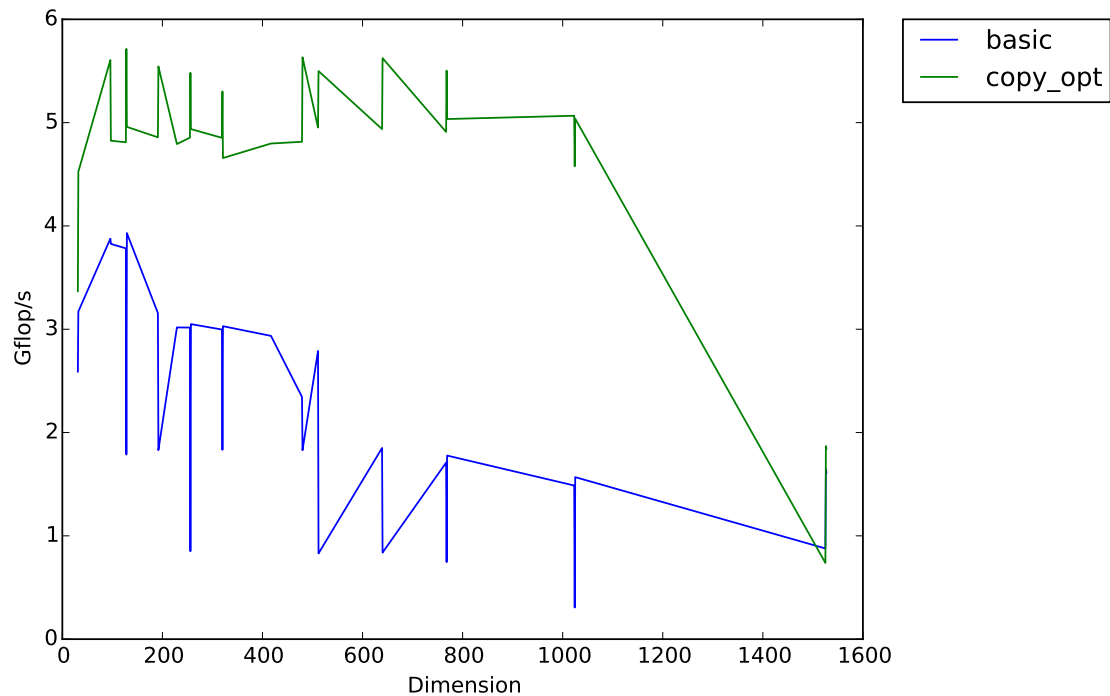


Figure 7: Basic DGEMM vs DGEMM with Copy Optimization

## 2.6 AVX Instructions

### 2.6.1 Approach

//Describe what we did here.

### 2.6.2 Results

//Add graphs here.

## 3 Next Steps

### 3.1 Copy Optimization with Blocks

### 3.2 Autotuning