Example Loop Optimizations

Loop fusion

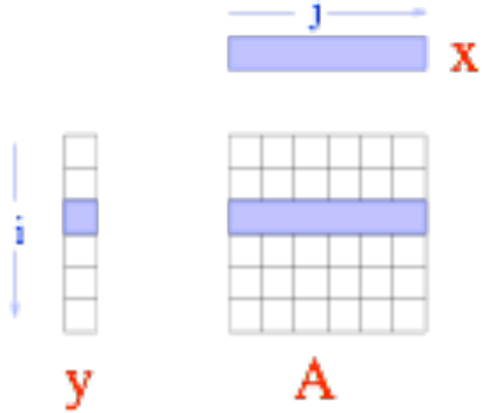
```
for (i = 0; i < N; i++)
   a[i] = 2 * a[i]
for (i = 0; i < N; i++)
   b[i] = a[i]
```


```
for (i = 0; i < N; i++)
   a[i] = 2 * a[i]
   b[i] = a[i]
```

- Merge two different loops together into a single loop
- Why is this useful? Improve reuse distance!
- May not always be legal

Loop interchange

- Change the order of a nested loop
- This is not always legal – it changes the order that elements are accessed!
- Why is this useful?
  - Consider matrix-vector multiply when A is stored in column-major order (i.e., each column is stored in contiguous memory)



y = Ax

```
for (i = 0; i < N; i++)
 for (j = 0; j < N; j++)
  y[i] += A[i][j] * x[j]
```

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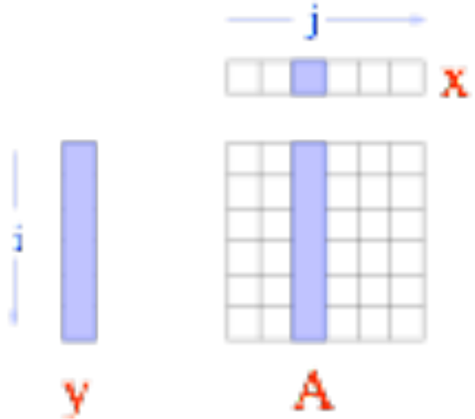


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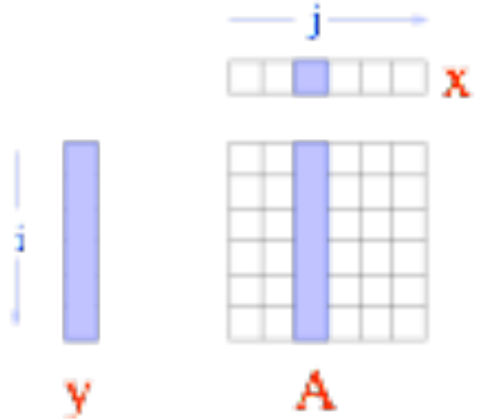
for (j = 0; j < N; j++)
 for (i = 0; i < N; i++)
  y[i] += A[i][j] * x[j]
```

Loop interchange

- What about x and y vectors?
  - Both vectors have reuse: each element is used N times
- Elements of vector indexed by outer loop has good reuse distance (same element used for each iteration of the inner loop)
- Elements of vector index by inner loop has bad reuse distance (same element is accessed after all other elements in the vector are accessed)
- Either have good reuse on the x vector and bad reuse on the y vector or vice versa

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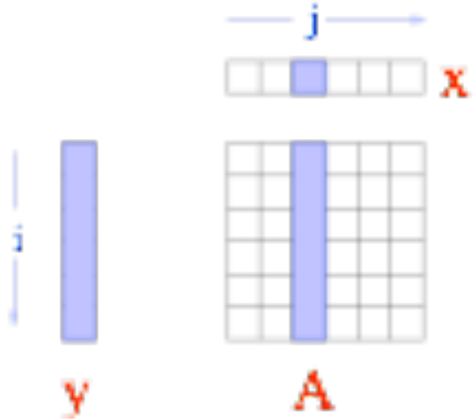


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Loop tiling

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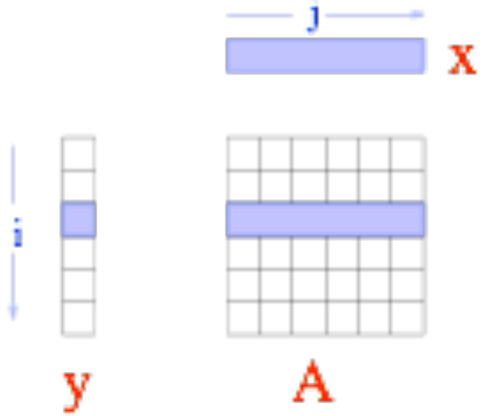
for (i = 0; i < N; i++)
 for (j = 0; j < N; j++)
  y[i] += A[i][j] * x[j]
```

- Also called “loop blocking”
- One of the more complex loop transformations
- Goal: break loop up into smaller pieces to get spatial and temporal locality
  - Create new inner loops so that data accessed in inner loops fit in cache
- Also changes iteration order, so may not be legal



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 for (j = 0; j < N; j++)
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```

```
for (ii = 0; ii < N; ii += B)
 for (jj = 0; jj < N; jj += B)
  for (i = ii; i < ii+B; i++)
   for (j = jj; j < jj+B; j++)
    y[i] += A[i][j] * x[j]
```