Parallel Programming (English)

(Week 4)

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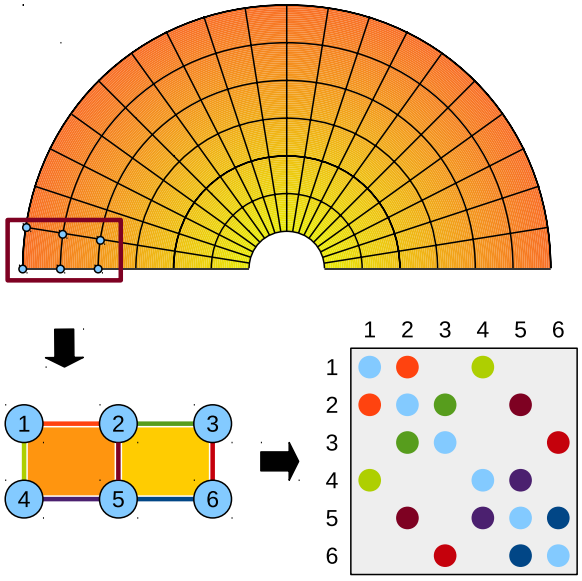
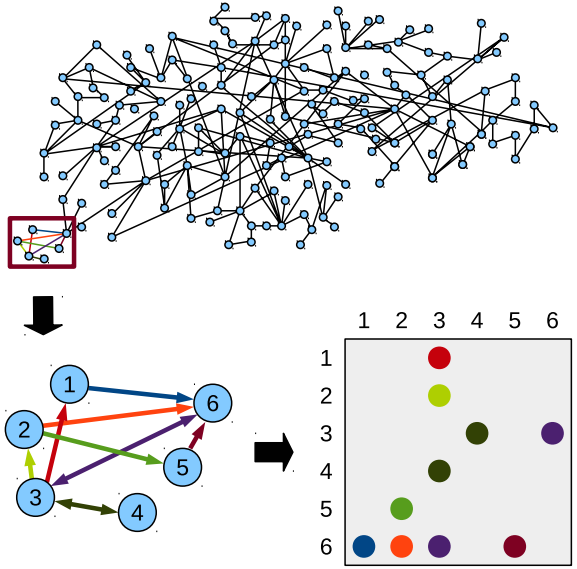
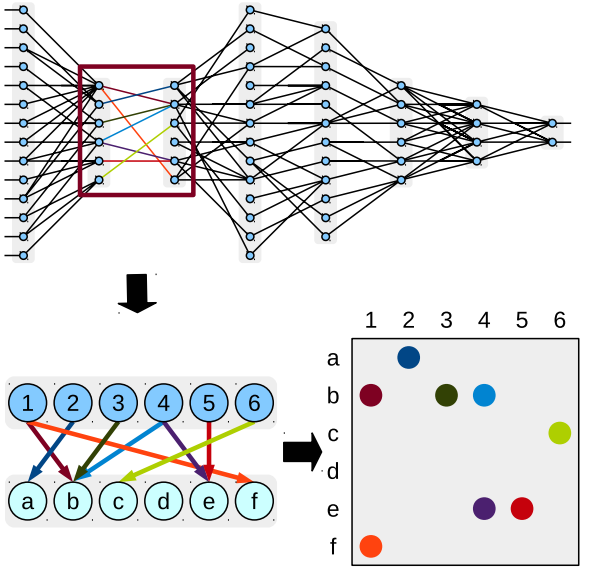
Sparse Matrices are everywhere



Finite element mesh,
Computational science



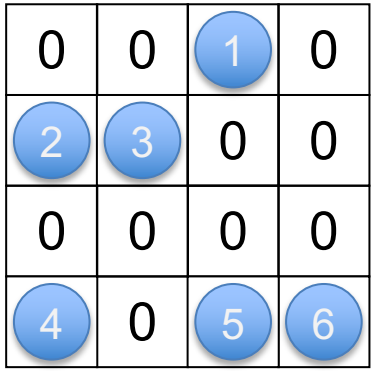
Social network,
Big Data Analytics



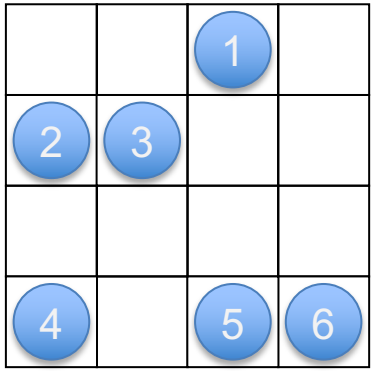
Deep neural network,
AI

Sparse Matrix and its Storage Format

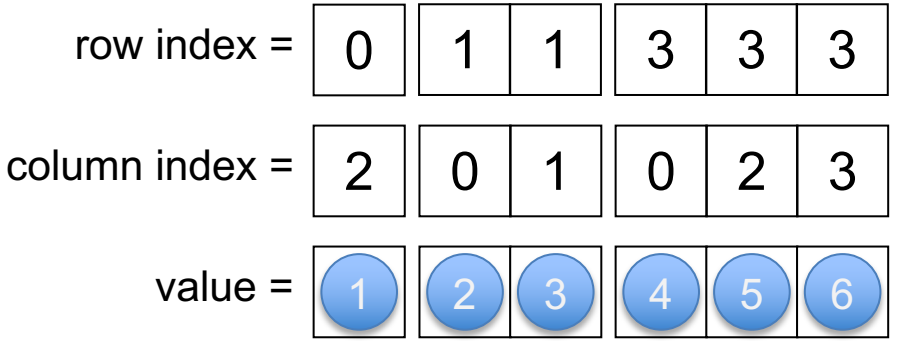
- If a matrix has a large amount of zeros, only storing its nonzeros may save overheads of memory space and computational resources.
- Coordinate (COO) and Compressed Sparse Row (CSR) formats can be used.



A
(4x4)
dense



A
(4x4)
sparse, 6 nonzeros



A (in COO)
(4x4)
6 nonzeros

Sparse Matrix and its Storage Format

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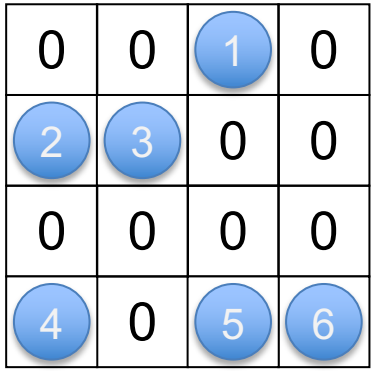
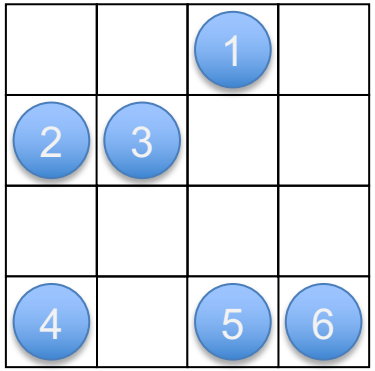
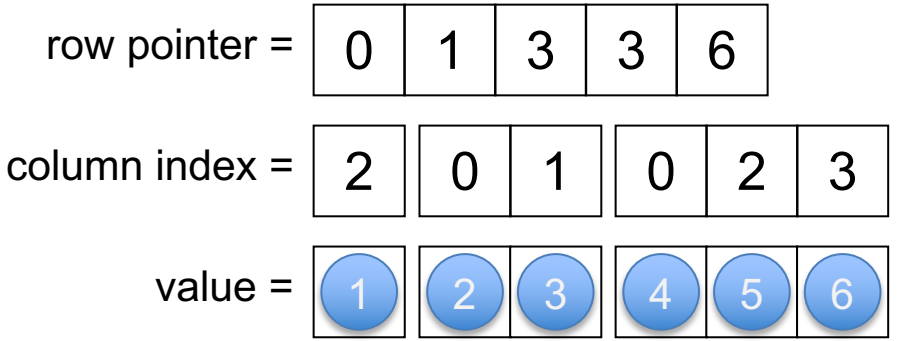


A
(4x4)
dense



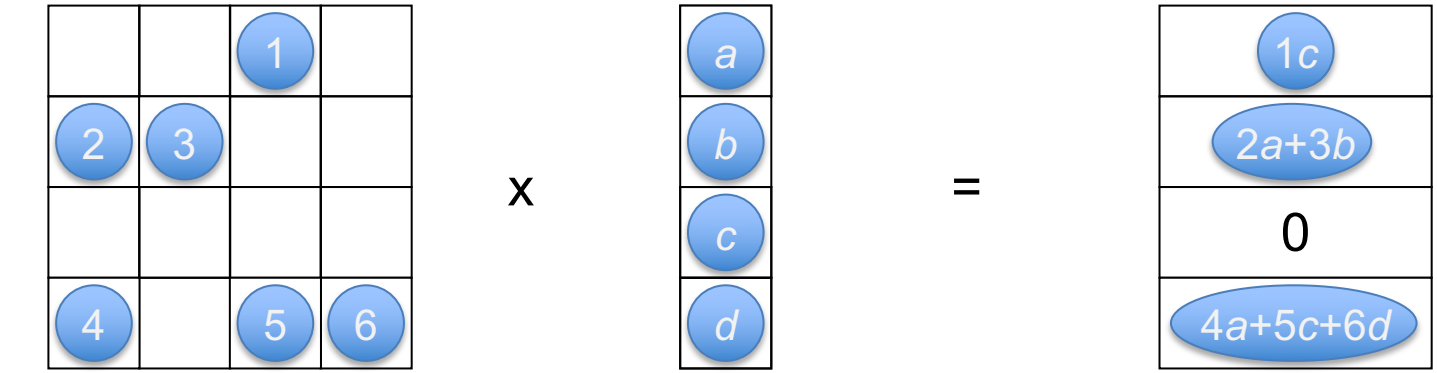
A
(4x4)
sparse, 6 nonzeros



A (in CSR)
(4x4)
6 nonzeros

Sparse Matrix-Vector Multiplication (SpMV)

- Multiply a sparse matrix with multiple vectors (or say, a talk-and-skiny matrix), and get multiple vectors (or say, a talk-and-skiny matrix).



A
(4x4)
sparse, 6 nonzeros

x
(4x1)
dense

y
(4x1)
dense

Sparse Matrix-Vector Multiplication (SpMV)

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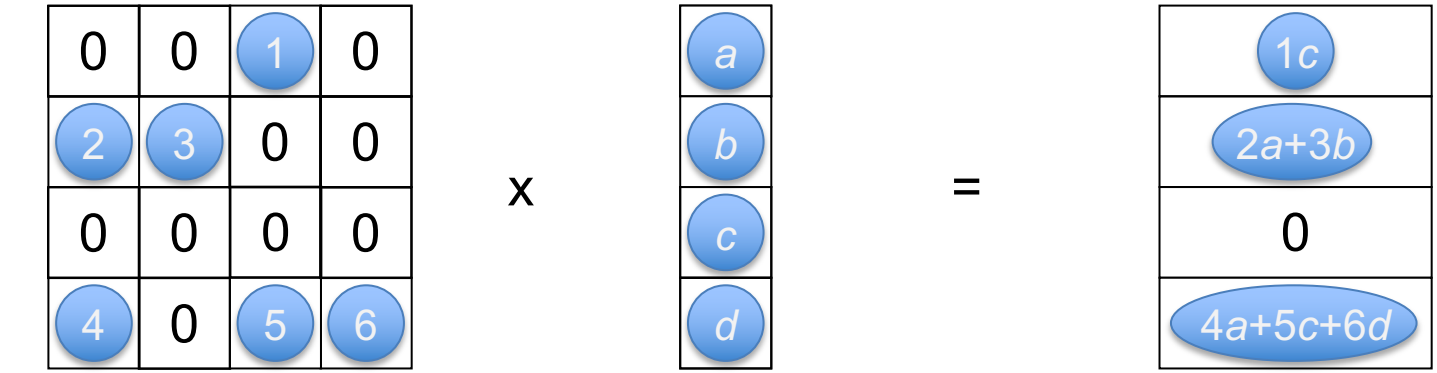

Sparse Matrix-Vector Multiplication (SpMV)

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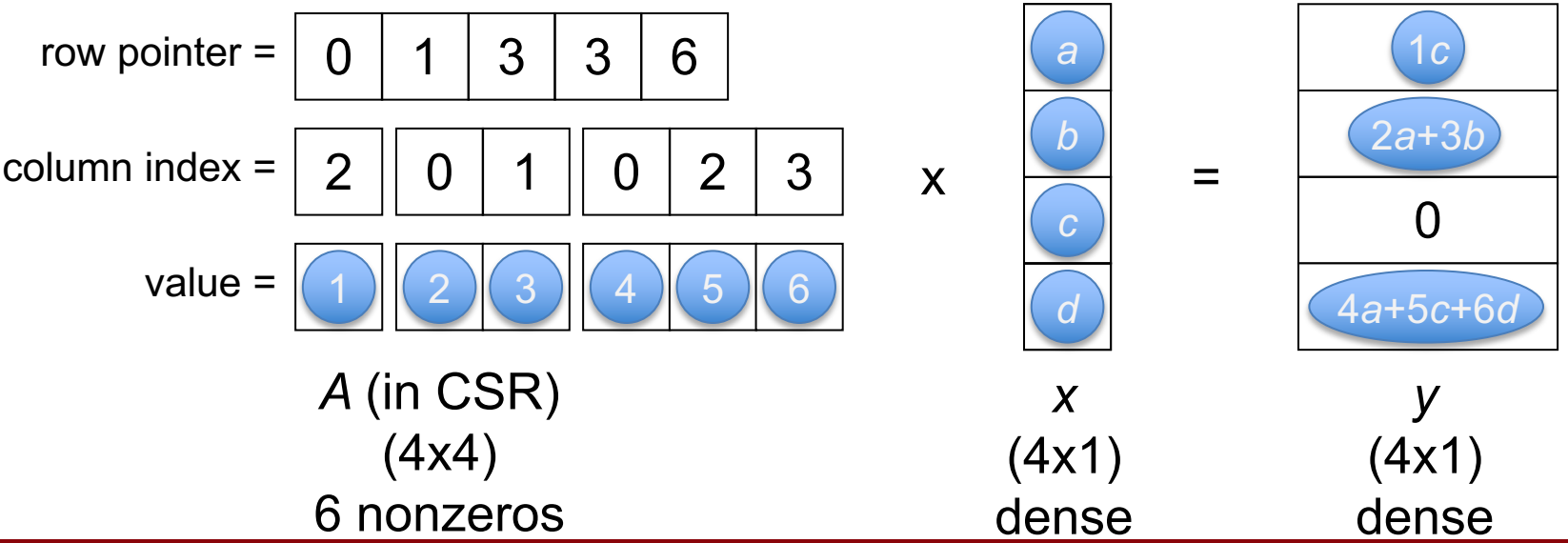


A (in CSR)
(4x4)
6 nonzeros

x
(4x1)
dense

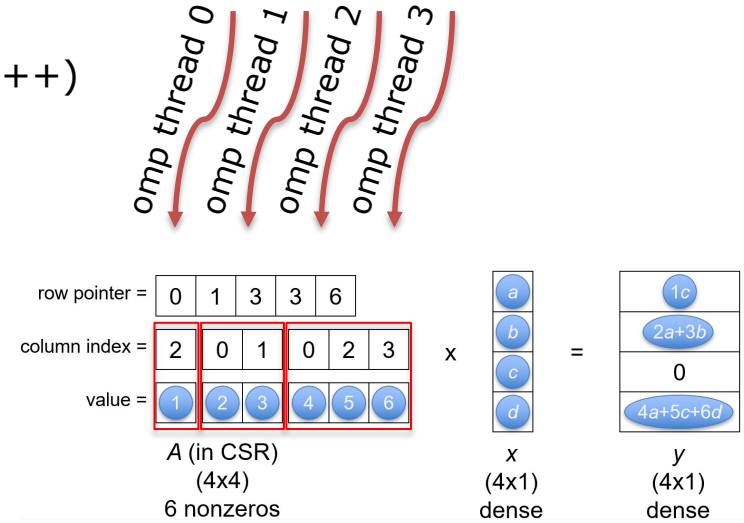
y
(4x1)
dense

Serial C code for SpMV

```
line 01: spmv (int n, int *row_ptr, int *col_idx, double *val, double *x, double *y)
line 02: {
line 03:
line 04:     for (int i = 0; i < n; i++)
line 05:     {
line 06:         y[i] = 0.0;
line 07:         for (int j = row_ptr[i]; j < row_ptr[i+1]; j++)
line 08:         {
line 09:             y[i] += val[j] * x[col_idx[j]];
line 10:         }
line 11:     }
line 12: }
```

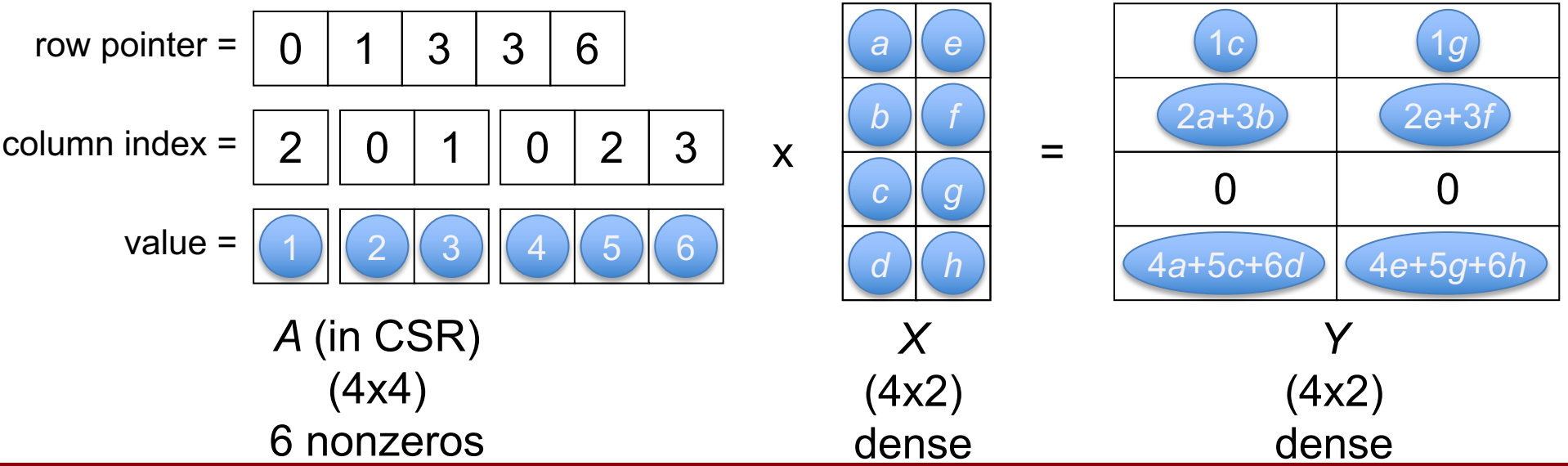
OpenMP C code for SpMV

```
line 01: spmv (int n, int *row_ptr, int *col_idx, double *val, double *x, double *y)
line 02: {
line 03:     #pragma omp parallel for
line 04:     for (int i = 0; i < n; i++)
line 05:     {
line 06:         y[i] = 0.0;
line 07:         for (int j = row_ptr[i]; j < row_ptr[i+1]; j++)
line 08:         {
line 09:             y[i] += val[j] * x[col_idx[j]];
line 10:         }
line 11:     }
line 12: }
```



Sparse Matrix-Multiple Vector Multiplication (SpMM)

- Multiply a sparse matrix with multiple vectors (or say, a talk-and-skiny matrix), and get multiple vectors (or say, a talk-and-skiny matrix).



A (in CSR)
(4x4)
6 nonzeros

X
(4x2)
dense

Y
(4x2)
dense

Thanks!