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LIBRSB: Multicore Sparse Matrix Performance across Languages and Architectures

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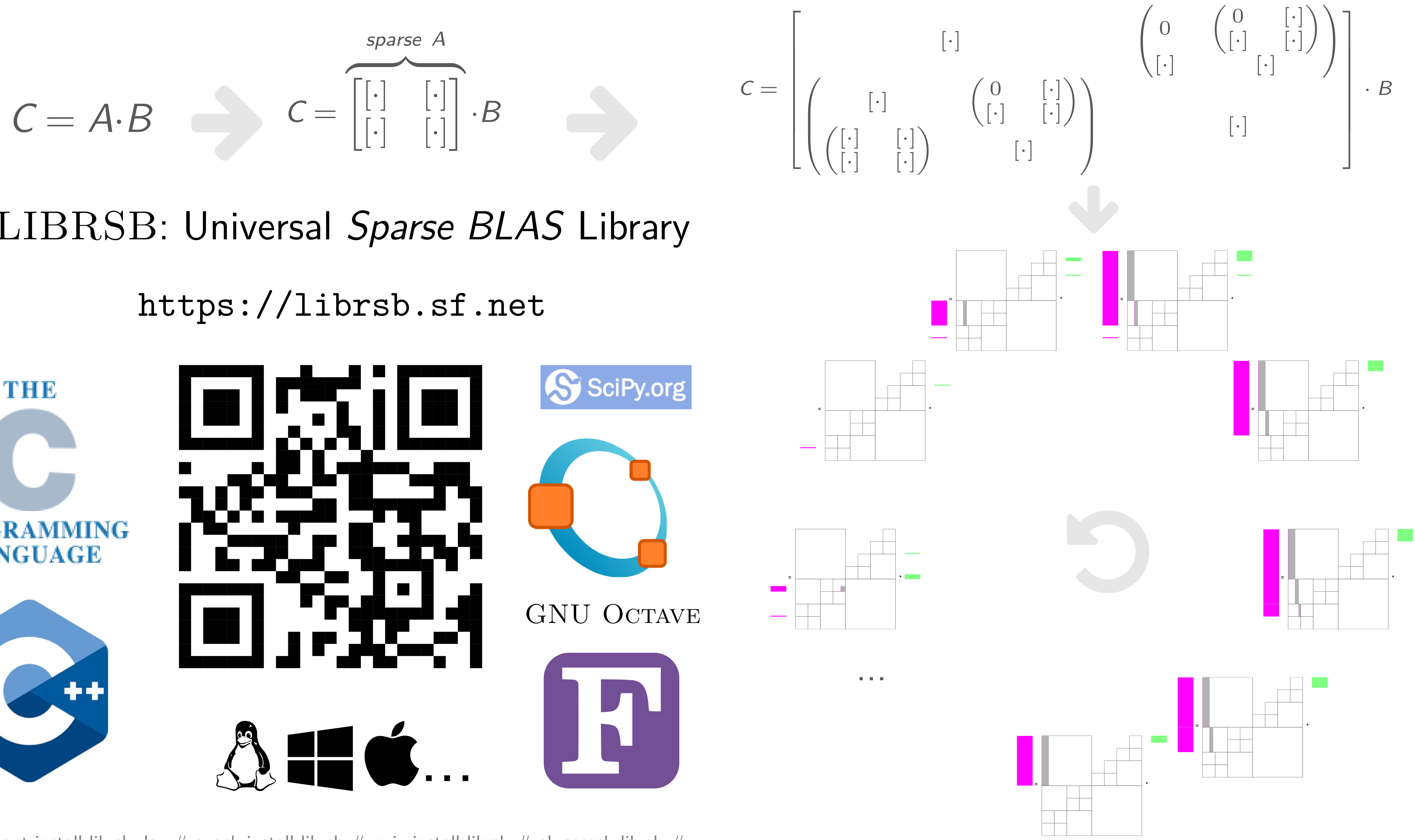


LIBRSB: Universal *Sparse BLAS* Library

https://librsb.sf.net

apt install librsb-dev # spack install librsb # guix install librsb # eb search librsb

Programming languages-related images with permission from www.octave.org, scipy.org, cplusplus.org, fortran-lang.org, wikipedia.org

A portable Sparse BLAS

- "Sparse *Basic Linear Algebra Subroutines*"
- for multicore CPUs (node-level)
- one library, multiple APIs
- **this poster: LIBRSB overview and ongoing work**

Numerical Techniques of Interest

- iterative methods: *block Krylov*
- require efficient Sparse Matrix-Matrix multiplication aka SpMM

SpMM in matrix form (m aka $NRHS$ aka *number of right hand sides*):

$$\underbrace{\begin{bmatrix} c_{11} & \dots & c_{1m} \\ \vdots & \ddots & \vdots \\ c_{n1} & \dots & c_{nm} \end{bmatrix}}_{\text{updated dense } C} \leftarrow \beta \underbrace{\begin{bmatrix} c_{11} & \dots & c_{1m} \\ \vdots & \ddots & \vdots \\ c_{n1} & \dots & c_{nm} \end{bmatrix}}_{\text{dense } C} + \alpha \underbrace{\begin{bmatrix} a_{11} & \dots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \dots & a_{nn} \end{bmatrix}}_{\text{sparse } A} \underbrace{\begin{bmatrix} b_{11} & \dots & b_{1m} \\ \vdots & \ddots & \vdots \\ b_{n1} & \dots & b_{nm} \end{bmatrix}}_{\text{dense } B}$$

LIBRSB

project page: http://librsb.sf.net

- >100KLOC of C99, OpenMP, and modern templated C++
- node-level **shared-memory**-parallel operations, for:
  - Sparse BLAS: matrix assembly/destroy, **SpMM**, triangular solve
  - *interactive* applications (update, sparse-sparse ops, conversions)
  - *distributed-memory applications* (block extract, update, etc.)
- – with own interface in C/C++ and Fortran
  - with Sparse BLAS interface (BLAS Technical Forum Standard)
  - with interfaces for GNU Octave and Python interpreters
- **LGPLv3-licensed** *free software*, available via Spack, Guix-HPC, EasyBuild, and on Debian, Ubuntu, OpenSUSE, Windows,...

Recursive Sparse Blocks (RSB) Layout

- for *large* matrices (uses *cache locality, coarse thread parallelism*)
- supports *autotuning* (*layout* adjusted to maximize performance)

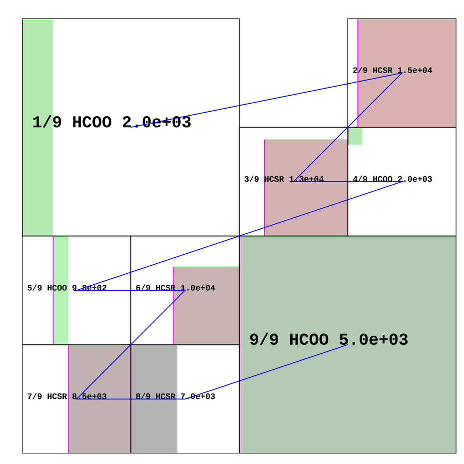


Figure 1: Instance of classical test matrix *bayer02* ($14k \times 14k, 64k$ nonzeroes). Black-bordered boxes are *sparse blocks*, and are Z-ordered. Greener have fewer nnz than average, redder have more. Either in *"Coordinate"* format (COO) or *"Compressed Sparse Rows"* (CSR). Blocks rows (LHS) and columns (RHS) ranges evidenced (left and top side).

Modern C++ interface (rsb.hpp)

```cpp
#include <rsb.hpp>
#include <vector>
#include <array>
using namespace ::rsb;

int main() {
  RsbLib rsblib;
  const int nnzA { 7 }, nrhs { 2 };
  const int nrA { 6 }, ncA { 6 };
  const std::vector<int>    IA {0,1,2,3,4,5,1};
  const int                 JA [] = {0,1,2,3,4,5,0};
  const std::vector<double> VA {1,1,1,1,1,1,2}, B(nrhs * ncA,1);
  std::array<double,nrhs * nrA> C;
  const double alpha {2}, beta {1};

  RsbMatrix<double> mtx(IA,JA,VA,nnzA);// Notice above declarations of IA,JA,VA

  mtx.spmm(RSB_TRANSPOSITION_N, alpha, nrhs, RSB_FLAG_WANT_ROW_MAJOR_ORDER, B,
    beta, C); // ditto for B and C
}
```

Figure 2: RsbMatrix's spmm() and others use C++20's std::span. Gives freedom in vectors' type choice. Wraps rsb.h.

GNU Octave + liboctave + LIBRSB = SparseRSB

- GNU Octave: a MATLAB-like interactive numerical language
- liboctave: access Octave via C++

```
octave:1> A = sparsersb ( sparse (rand (3) > .6) )
A =

Recursive Sparse Blocks  (rows = 3, cols = 3, nnz = 2 [22%])

  (3, 1) -> 1
  (3, 3) -> 1
```

Figure 3: The sparsersb usage is styled after the sparse built-in. So most of operators (*,*=,(:),...) work the same way.

Python + Cython + LIBRSB = PyRSB

- SciPy: popular Python scientific computing API
- Cython: *optimising static compiler* for C extensions to Python

```python
import numpy
import scipy
from rsb            import rsb_matrix
V=[ 11.,12.,22.]
I=[   0,   0,   1]
J=[   0,   1,   1]
a = rsb_matrix((V, (I, J)), [3,3])
 ...
y = y + a * x;
```

Figure 4: API styled after SciPy's widely known csr_matrix. Additionally, it offers RSB-specific functionality, e.g. blocks autotuning.

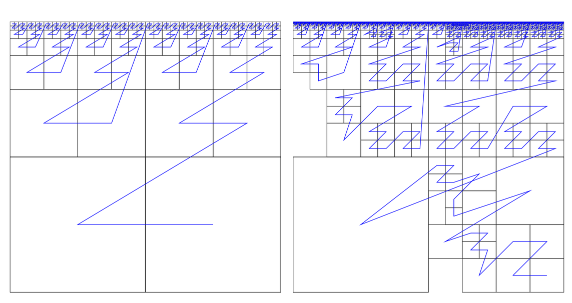
New: ongoing work

Improve performance of SpMM CSR kernels:

- AVX512 intrinsics (*by-rows*, unsymmetric, untransposed)
- more specializations
- autotuning challenges: e.g. use CSR if more performant than RSB

Remarks

Two RSB block layouts (a *coarser* left, a *finer* right) of a Machine Learning matrix sized $57k \times 230k$ and 41M nonzeroes (courtesy Dr. Diego De Cao). This matrix is particularly favourable to RSB over CSR. Determining optimal blocking and threads is eased by the autotuning functionality.



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