GraphBLAS Forum Updates

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Content provided by Benjamin Brock (Intel), Tim Davis (TAMU), James Kitchen (Anaconda), Manoj Kumar (IBM), Roi Lipman (Redis), Tim Mattson (Intel), Erik Welch (NVIDIA) and many others.
Introduction

The graph $A^T$ from vertex $v$ is equal to $A^T v$. 

![Graph Diagram]
GraphBLAS Forum Information

**Website:** [http://graphblas.org](http://graphblas.org)
- Lists workshops and conferences
- Link to the latest C API Specification
- Lists teams developing implementations
- Other useful resources including the “The Math Document”

**Mailing list:** Graphblas@lists.lbl.gov
- Hosted by LBL ([mailto:abuluc@lbl.gov](mailto:abuluc@lbl.gov))
- Join the Forum by joining the list

**Monthly teleconference:**
- Second Friday of every month, 12pm Eastern Time
- Send email to Jeremy Kepner to receive the calendar invite and Zoom ID.
GraphBLAS API Committees (we have reorganized)

**C++ Subcommittee:** Aydın Buluç, Tim Mattson, Scott McMillan, José Moreira, Benjamin Brock.
- C++ API Specification: under development
- Future: Distributed computing

**C Subcommittee:** Jim Kitchen, Erik Welch, Tim Mattson, Manoj Kumar, Will Kimmerer.
- C API Specification: Version 2.1 with type introspection and enhancements to address the needs of emerging applications (such as GNNs, and graph database queries).

**“Math” Subcommittee:** TBD.
- Defines the mathematical behaviour that should be implemented by a GraphBLAS library and can be referenced by any language API.

Note: We are *not* planning to create committees/APIs for languages other than C/C++
GraphBLAS in the real world

- Language Bindings
  - C
  - Python
  - C++
  - Julia
  - others on the way…Go, Java, etc.

- Reference implementation: SuiteSparse:GraphBLAS

- LAGraph Algorithms Repository

- Commercial endeavors
  - Mathworks: MATLAB
  - RedisLabs: RedisGraph database
  - …and all the customers using those packages
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Not just a research project anymore.
C API

Will Kimmerer, Jim Kitchen, Manoj Kumar, Tim Mattson, Erik Welch
C API Updates

Expecting a new **minor release in 2023, version 2.1**

- **Type introspection** – the LAGraph work has shown this is essential for building libraries on top of the GraphBLAS.

Also considering numerous additional features including:

- Macros to identify library release information
- User defined Monoids with terminal values
- Query interface for monoids, semirings, operator domains, and execution modes.
- User-specified allocators/deallocators to use
- Miscellaneous refinements to existing operators and operations
Python
Jim Kitchen, Eric Welch
python-graphblas (was grblas)

- Python wrapper around SuiteSparse:GraphBLAS with a more functional programming style
- Provides access to all GxB features in SuiteSparse
- Additional features:
  - Call Recorder – automatically generate equivalent C calls from Python code
  - Aggregators – advanced reductions (ex. avg, stdev, root mean square)
  - selectk – select the [first|last|smallest|largest|random] k elements from each row
- Easy to install (win/mac/linux, x86/arm64, wheels or conda)

graphblas-algorithms

- Similar concept to LAGraph, but written using python-graphblas
- 40+ algorithms so far (goal to implement majority of Networkx algorithms)
- Will be used in NetworkX 3.0 fast-dispatching feature
C++ API Specification

Benjamin Brock, Scott McMillan, Tim Mattson, José Moreira, and Aydı̈n Buluç
C++ Spec “Aspirations” (Design Goals)

- Better support for **user-defined types**
  - First-class user-defined types
  - Non-memcpy-able scalar types
  - User-defined index types
  - First-class user-defined operators (including lambdas)

- **Interoperability** with Standard Template Library

- Pathway for **advanced features**
  - Distributed memory
  - GPU (device) support
Generic Containers
Matrix Data Structure

```
grb::matrix<float>
```

Type of stored values
Matrix Data Structure

grb::matrix<\texttt{float}, \texttt{int}>

- Type of stored values
- (Integer) type used to store indices
Matrix Data Structure

grb::matrix<float, int, grb::column>

Type of stored values

(Integer) type used to store indices

Compile-time hint about storage format
Matrix Data Structure

grb::matrix<float, int, grb::column, my_alloc<float>>

- Type of stored values
- (Integer) type used to store indices
- Compile-time hint about storage format
- Allocator
Matrix Data Structure

grb::matrix<\texttt{float}, \texttt{int}, grb::column, my_alloc<\texttt{float}>>

- **Type of stored values**: \texttt{float}, \texttt{int}
- **(Integer) type used to store indices**: \texttt{int}
- **Compile-time hint about storage format**: \texttt{column}
- **Allocator**: my_alloc<\texttt{float}>

Optional
Interoperability

- **Allocators** support
  - GPUs/device memory
  - Persistent memory
  - Any framework that wants to control memory allocation

- **Concepts** support interoperability with the **C++ Standard Library and user applications**
  - Matrices and vectors are Ranges
  - Views on matrices and vectors (transposes, rows, transforms, etc…)
  - Matrix concepts allow users to adapt their data structures to GraphBLAS

```cpp
// Select a particular GPU
auto my_gpu = sycl::device(sycl::gpu_selector());

// Create allocator for `my_gpu`
auto alloc = sycl_tools::device_allocator<int>(my_gpu);

// Create matrix using GPU allocator
grb::matrix<float, int, grb::row, 
sycl_tools::device_allocator<int> >
  matrix({1024, 1024}, alloc);

// ...

// Using STL Algorithms
auto r = std::ranges::reduce(matrix);
```
Algorithms (GraphBLAS Operations)
GraphBLAS Operations – Overloading and Optional Arguments

Current draft introduces **multiply**, which multiplies **vectors** and/or **matrices**

**Optional arguments** and **overloading** results in cleaner syntax.

```cpp
grb::matrix<float> a("chesapeake.mtx");
grb::vector<bool> x(a.shape()[1]);
x[5] = true;

// Default plus/times operators, "full mask"
auto b = grb::multiply(a, x);

// Equivalent, but explicitly declare operators
auto b_p = grb::multiply(a, x, grb::plus(), grb::times());

// Multiply with an explicit mask
auto next = grb::multiply(a, b, grb::plus(), grb::times(), x);
```
Operators
Binary Operators

Binary operators are implemented similarly to STL’s `<functional>`

Can specify one or more types, or leave them to be deduced

Allows use of inline specifications like lambdas (not shown)

```cpp
// Automatically deduce types of plus, times
auto b_p = grb::multiply(a, x, grb::plus(),
                         grb::times());

// Everything in floating point
auto next = grb::multiply(a, b, grb::plus<float>(),
                           grb::times<float>());

// Multiply in float, reduce in double
auto next = grb::multiply(
    a, b,
    grb::plus<double>(),
    grb::times<float, float, double>());
```
Draft spec is accessible…Feedback Welcome

Check out the spec:

https://github.com/GraphBLAS/graphblas-api-cpp

Check out the rgri reference implementation:

https://github.com/GraphBLAS/rgri
SuiteSparse: GraphBLAS

Timothy Davis, TAMU
SuiteSparse:GraphBLAS v7.2.0. Progress since 2021

• Conforms to the v2.0 C API (Nov 2021)
  • GrB_Scalar, GrB_IndexUnaryOp, GrB_serialize/deserialize with ZSTD compression

• New GxB features:
  • pack/unpack (O(1)-time move semantics)
  • named types and operators (for future JIT)
  • matrix and vector sort
  • eWiseUnion (like eWiseAdd but with 2 scalars; all entries in output go through the operator)
  • matrix and vector iterators
  • matrix reshape

• Performance:
  • GrB_mxm, particularly with sparse-times-dense or dense-times-sparse. AVX2 and AVX512 exploit
  • faster MATLAB interface

• Port to Octave 7
• Supported by Intel, NVIDIA, Redis, MIT Lincoln Lab, MathWorks, Julia Computing
SuiteSparse versus the Intel MKL sparse library

<table>
<thead>
<tr>
<th>computation</th>
<th>format</th>
<th>MKL method</th>
<th>MKL time (sec)</th>
<th>SuiteSparse time (sec)</th>
<th>speedup</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1st</td>
<td>2nd</td>
<td>1st</td>
</tr>
<tr>
<td>y+=S*x</td>
<td>S by row</td>
<td>mkl_sparse_d_mv</td>
<td>2.54</td>
<td>1.27</td>
<td>1.21</td>
</tr>
<tr>
<td>y+=S*x</td>
<td>S by col</td>
<td>mkl_sparse_d_mv</td>
<td>7.22</td>
<td>7.22</td>
<td>1.98</td>
</tr>
<tr>
<td>C+=SxF</td>
<td>S by row, F by row</td>
<td>mkl_sparse_d_mm</td>
<td>2.95</td>
<td>1.90</td>
<td>1.98</td>
</tr>
<tr>
<td>C+=SxF</td>
<td>S by row, F by col</td>
<td>mkl_sparse_d_mm</td>
<td>6.12</td>
<td>4.99</td>
<td>1.48</td>
</tr>
<tr>
<td>C+=SxF</td>
<td>S by col, F by row</td>
<td>mkl_sparse_d_mm</td>
<td>28.82</td>
<td>28.82</td>
<td>13.78</td>
</tr>
<tr>
<td>C+=SxF</td>
<td>S by col, F by col</td>
<td>mkl_sparse_d_mm</td>
<td>78.82</td>
<td>5.17</td>
<td>9.38</td>
</tr>
<tr>
<td>C=S+B</td>
<td>S by row</td>
<td>mkl_sparse_d_add</td>
<td>30.77</td>
<td>30.77</td>
<td>1.44</td>
</tr>
<tr>
<td>C=S'+B</td>
<td>S by row</td>
<td>mkl_sparse_d_add</td>
<td>102.09</td>
<td>27.30</td>
<td>16.29</td>
</tr>
<tr>
<td>C=S'</td>
<td>S by row</td>
<td>mkl_sparse_convert_csr</td>
<td>77.27</td>
<td>77.27</td>
<td>14.80</td>
</tr>
</tbody>
</table>

Table 4. SuiteSparse vs MKL 2022 with the GAP-Twitter matrix
Work in progress and future work

- **Faster hypersparse matrices** (the “hyperhash”, avoids binary search), in v7.3.0beta
- **CUDA acceleration** (with J. Eaton and C. Nolet, NVIDIA): *3x to 9x speedup in GrB_mxm*
- **Julia integration** (just announced v0.7), replacing Julia SparseArrays
  - more MATLAB integration
  - further Python integration
  - RedisGraph future: faster, more features
  - JIT for faster user-defined types and operations
  - aggressive non-blocking mode, kernel fusion
  - \(x=A\backslash b\) over a field
  - more built-in types (FP16, complex integers, …)
  - faster kernels (GrB_mxm for sampled dense-dense matrix multiply)
  - matrices with shallow components
  - …

https://github.com/DrTimothyAldenDavis/GraphBLAS
LAGraph: graph algorithms library

LAGraph: graph algorithm library

Version 1.0 released in September 2022

6 polished, stable algorithms (the GAP benchmark):
  • Breadth-first search
  • Betweenness-centrality
  • PageRank
  • Connected Components
  • Single-source Shortest-Path
  • Triangle Counting

Stable utilities
  • malloc/calloc/realloc/free wrappers
  • create/destroy the LAGraph_Graph
  • compute properties: degree, A', # diag entries
  • delete properties
  • display graph
  • Matrix Market file I/O (very slow)
  • Sorting
  • thread control
  • timing
  • type management

Many experimental algorithms to be curated
  • K-truss, All K-truss
  • Bellman-Ford single-source shortest path
  • Maximal independent set
  • Triangle Centrality
  • Community detection w/ label propagation
  • Deep Neural Network Inference
  • Strongly Connected Components
  • Minimum Spanning Forest
  • Local Clustering Coefficient
  • K-core
  • Counting all size-4 graphlets
  • Triangle polling
  • Fiedler vector

Experimental utilities
  • random matrix, vector generators
  • Binary matrix file I/O (very fast), serialize/deserialize, parallel LZ4 comp.

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RedisGraph

Roi Lipman
Property Graph DB

- Nodes represent entities
- Edges represent relations between entities
- Nodes & Edges associated with Attributes

Name: Adam
Age: 42
Citizenship: Canadian

Airline: United
Origin: Toronto
Destination: Dallas

• Nodes represent entities
• Edges represent relations between entities
• Nodes & Edges associated with Attributes
Query graphs

MATCH (f1:Flight)<-[isAboard]-(Person)-[isAboard]->(f2:Flight)
RedisGraph Use Cases

- Social networks
- Supply chain optimization
- Fraud detection/prevention
- Resource management
- Access control

To learn more

https://redis.io/docs/stack/graph/
Questions?

Website: [http://graphblas.org](http://graphblas.org)
- Lists workshops and conferences
- Links to the latest API Specifications
- Teams developing implementations
- Other useful resources

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Python GraphBLAS bindings:
- [https://github.com/python-graphblas/python-graphblas](https://github.com/python-graphblas/python-graphblas)
- [https://github.com/python-graphblas/graphblas-algorithms](https://github.com/python-graphblas/graphblas-algorithms)

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RedisGraph: [https://redis.io/docs/stack/graph](https://redis.io/docs/stack/graph)