Electrical & Computer ENGINEERING
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Code Generation for Complex Valued Linear Algebra

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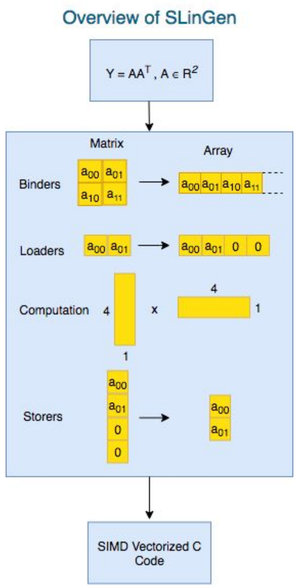
The Motivation

SLinGen[1,2] is a code generator for small scale linear algebra applications

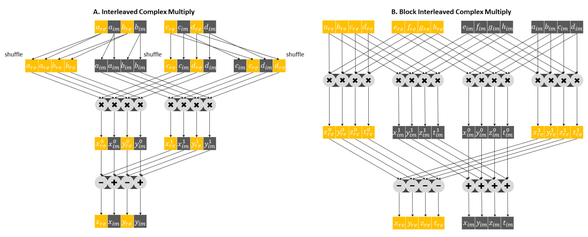
Currently SLinGen targets only real-valued applications

Our Goal: Extend SLinGen to generate code for complex dense linear algebra applications



Picking a Storage Layout

Complex Multiplication with SIMD instructions[3]

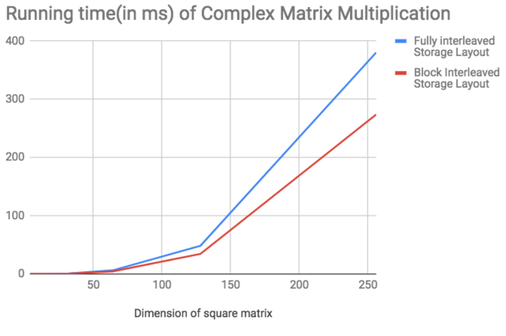


Fully Interleaved Layout: Poorer performance from additional shuffle instructions

Block Interleaved Layout: Better performance since no additional shuffles required

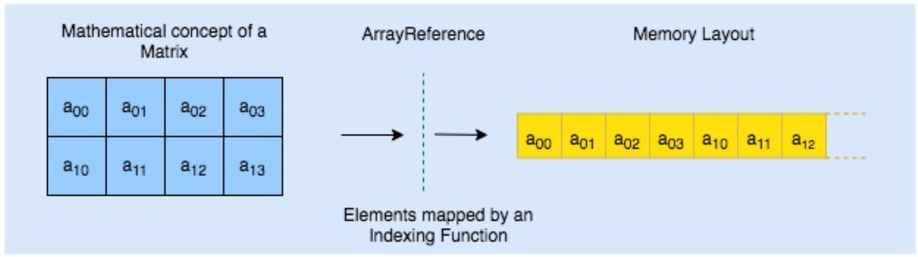
Storage Layouts affect Performance!

Experimental Setup: Intel Core i7-7700K(Kaby Lake microarchitecture) 4.20 GHz, 256kB L1 Cache , 1MB L2 Cache

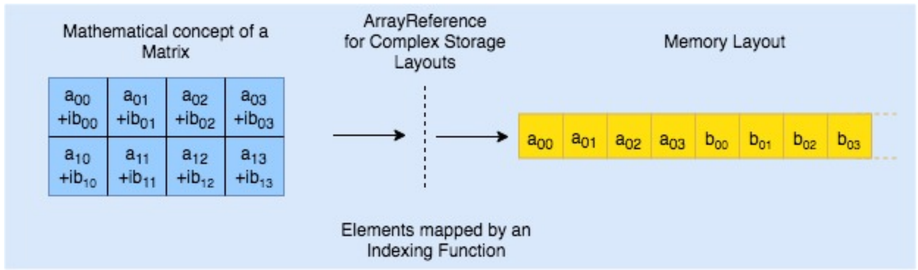


Mapping Math to Memory

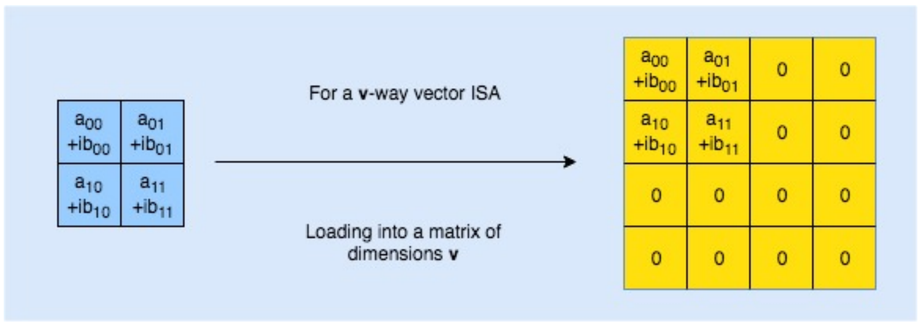
Reference types translate matrix element accesses to physical layout accesses



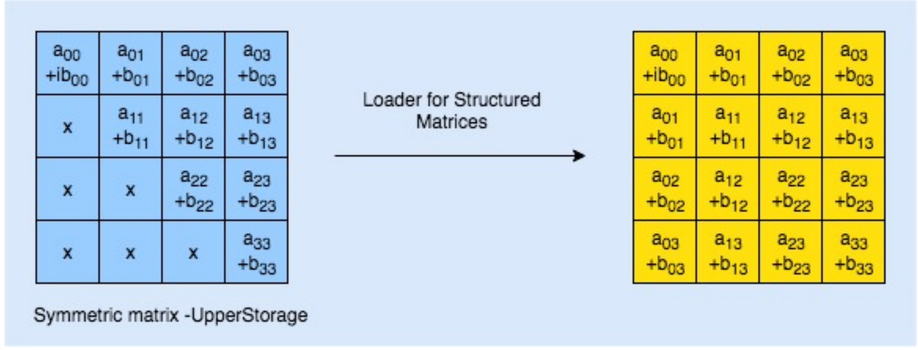
New Reference Type for Block Interleaved Storage Layout of Complex Matrices



Loading and Storing



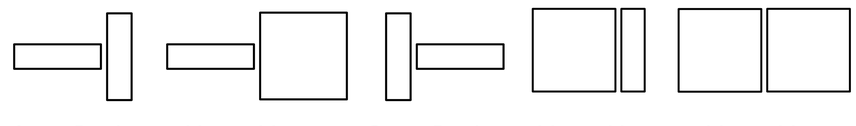
New Loaders and Storers for complex matrices. Both real and imaginary parts have to be packed



New Computational Units

Example for Complex Matrix Multiplication

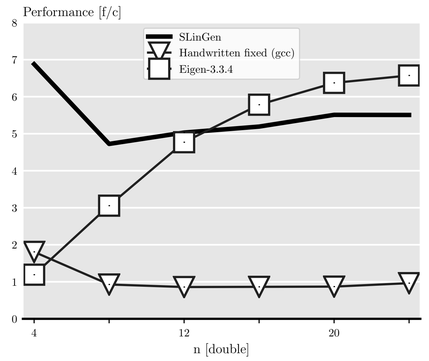
Building blocks that can be implemented efficiently for any ISA



Results

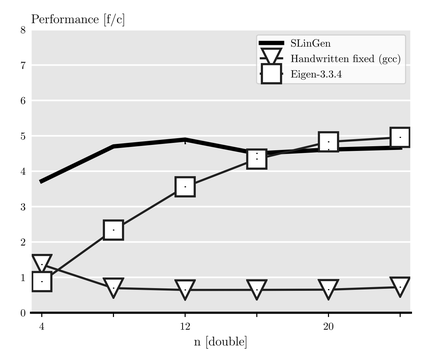
Performance (Flops/Cycle) vs Dimensions of Matrices

Experimental Setup: Intel Core i7-4790K (Haswell microarchitecture) 4.00 GHz, 256kB L1 Cache , 1MB L2 Cache



Complex General Matrix-Matrix Multiply

C = A*B + C



Complex Symmetric-General Matrix Multiply

C = S*A

Competitors:

- Hand written kernel vectorized by gcc auto-vectorize
- Eigen[4]: C++ template library for linear algebra

Future Work

- Performance improvement from handling register spills
- Support for mixed data type kernels

Acknowledgement

The authors wish to thank Tze Meng Low and Thom Popovici for fruitful discussions and suggestions during the course of the project.

References

[1] SLinGen - source code hosted at https://github.com/danielesgit/slingen

[2] D. G.Spampinato and M. Püschel, "A Basic Linear Algebra Compiler for Structured Matrices", In Code Generation and Optimization (CGO), pp 117-127, 2016

[3] D.T. Popovici, F. Franchetti and T. M. Low, "Mixed Data Layout Kernels for Vectorized Complex Arithmetic", in High Performance Extreme Computing (HPEC), pp 1-7, 2017

[4] Eigen C++ Template Library: http://eigen.tuxfamily.org