Overreaching with Outreach: Is HPC in Reach?

Maggie Myers

Robert van de Geijn

Are we crazy?

Three Massive Open Online Courses:

- Linear Algebra: Foundations to Frontiers
- LAFF-On Programming for Correctness
- (LAFF-On) Programming for HPC

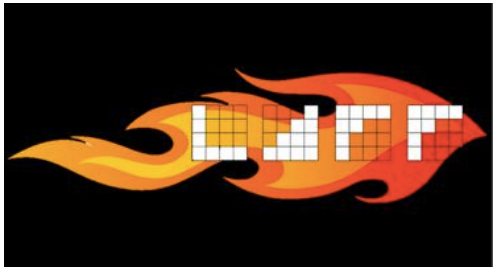
Educating the world about our world.

Insights for HPC we want to share

- When presenting algorithms, abstract away from details.
- When representing algorithms in code, use APIs.
- When optimizing or parallelizing, don't just start with legacy code. Derive families of algorithms.
- When implementing software, layer.
- When sharing gained insights use the simplest examples.

Where are we in our journey?

- LAFF
  - Sixth offering on edX.
- LAFF-On Programming for Correctness
  - First offered Spring 2017
- Programming for HPC
  - Planning



What is LAFF?

- Linear Algebra: Foundations to Frontiers (LAFF)
- A full semester class
- Connects the abstractions in mathematics with algorithms and their instantiation in code.
  - Layering of matrix-matrix/matrix-vector/vector-vector operations linked to layering with BLAS.
- Targets novices and those who want a refresher.
- Enriches fundamental linear algebra with HPC issues.
- Introduces FLAME notation and, in enrichments, acquaints the world with our research.

Linear Algebra: Foundations to Frontiers

You will learn to

Slice and Dice

- Recognize, apply, verify, and make connections between properties of vectors and their operations including geometric interpretations, orthogonality, length, vector algebra, and representations as linear combinations of unit basis vector.
- Develop and evaluate algorithms for matrix and vector operations.
- Make use of decomposition and blocking methods as well as recognize, develop and apply special characteristics of matrices including whether a matrix is triangular, symmetric, diagonal, and invertible.

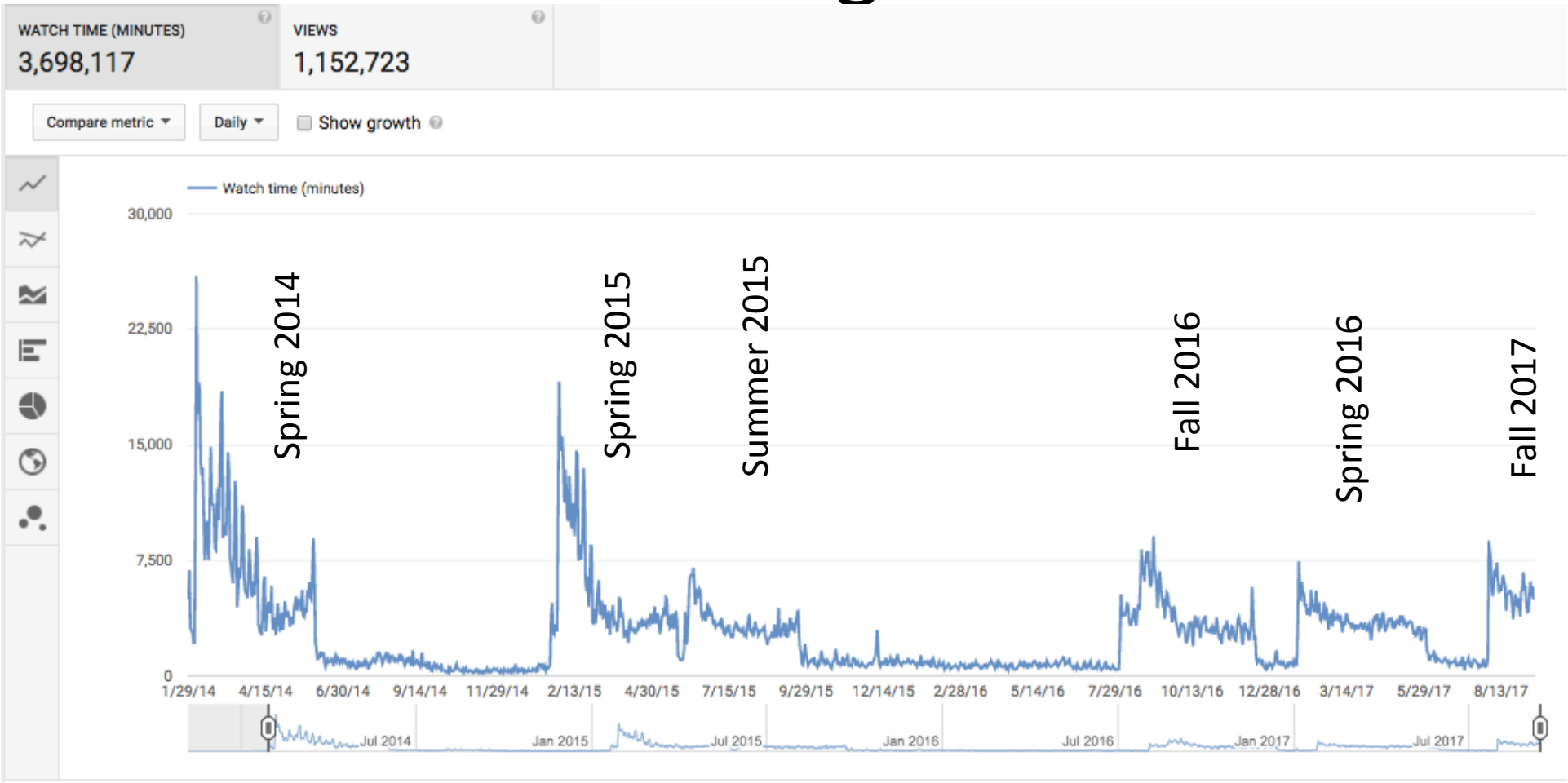
Transform and Solve

- Recognize, apply, and verify properties of linear transformations, including their connection to matrices and systems of linear equations.
- Determine solutions for systems of equations by applying a variety of methods including Gaussian elimination as well as various LU and QR factorization methods, and compare and contrast the different approaches.
- Find eigenvalues and eigenvectors of a matrix.

Abstract

- Develop and evaluate a variety of algorithms for determining the solutions of systems.
- Understand and apply notions such as span, column space, null space, rank, and linear independence in the context of vector spaces and subspaces.
- Recognize, develop, and apply various characterizations of linear independence.
- Create a small library of basic linear algebra subroutines.

How’s it goin’?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VIEWS
1,152,723
Compare metric
Daily
Show growth
Watch time (minutes)
30,000
22,500
15,000
7,500
0
Spring 2014
Spring 2015
Summer 2015
Fall 2016
Spring 2016
Fall 2017
1/29/14
4/15/14
6/30/14
9/14/14
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7/15/15
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12/14/15
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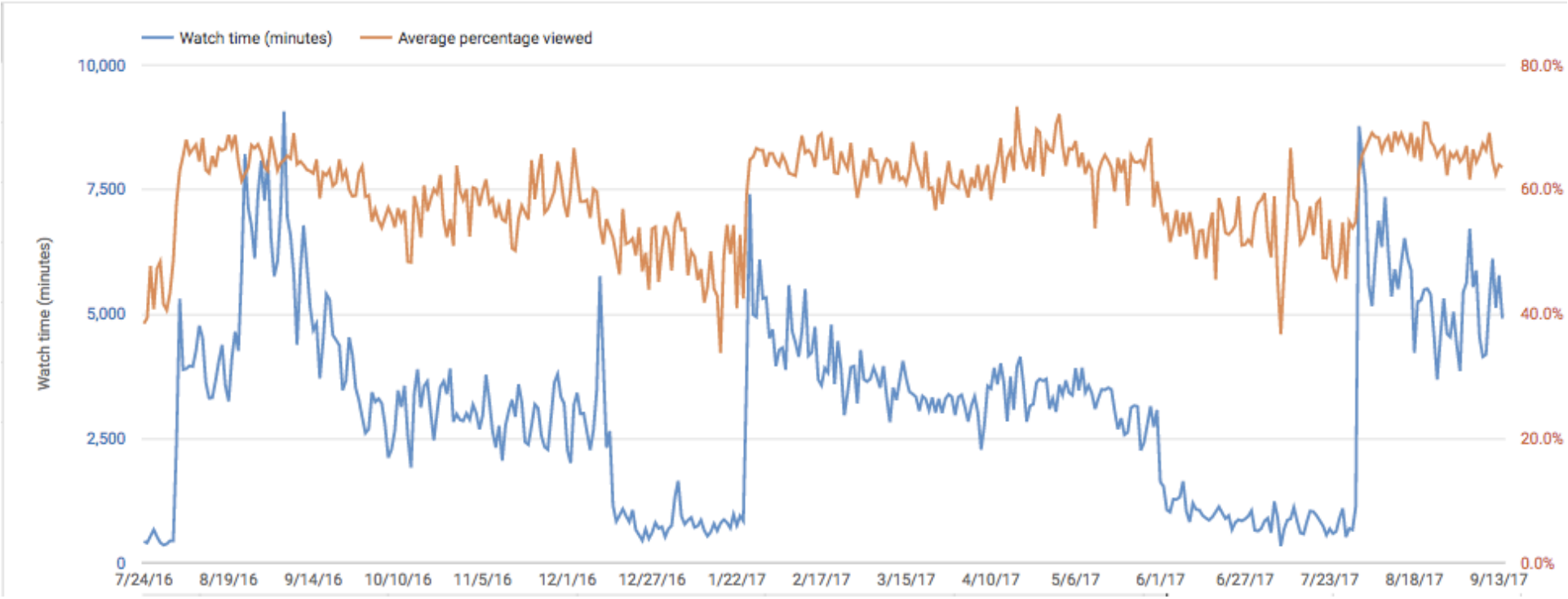
How’s it goin’?

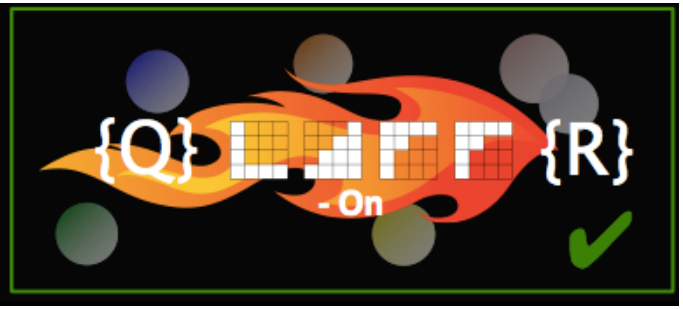


Fall 2016 Spring 2016 Fall 2017

LAFF-On Programming for Correctness

- For many HPC applications, including dense matrix computations, implementations of key operations are loop-based.
- Classic techniques developed in the 1960s by Dijkstra et al. use a loop invariant and the Principle of Mathematical Induction to prove a loop correct.
- FLAME Notation hides indices and facilitates formal derivation of families of algorithms.
- *A priori* determination of loop invariants.
- Important for HPC: best algorithm for situation can be chosen.

LAFF-On Programming for Correctness



Foundations…

Annotate programs with assertions about the states of variables.

Prove programs correct with Hoare triples and weakest preconditions.

Apply goal oriented programming techniques to derive programs hand-in-hand with their proofs of correctness

Frontiers…

Avoid indexing errors by avoiding indexing.

Determine loop invariants *a priori*.

Develop families of algorithms for matrix and vector operations.

How’s it goin’?


WATCH TIME (MINUTES)
47,170
VIEWS
16,060
Compare metric
Daily
Show growth
Watch time (minutes)
1,600
1,200
800
400
0
4/2/17
4/20/17
4/29/17
5/8/17
5/17/17
5/26/17
6/13/17
6/22/17
7/1/17
7/19/17
7/28/17
8/6/17
8/15/17
8/24/17
9/11/17
First offering
On campus course
First six weeks

The beat goes on…

And now (LAFF-On) Programming for HPC

- Illustrate issues in HPC with simple example: matrix-matrix multiplication (gemm)

Envision three parts:

- Optimizing gemm (for single core and multicore)
- Data movement on distributed memory architectures (MPI and collective communication)
- Parallelizing gemm to distributed memory

Resources

- K. Goto and R. van de Geijn. **Anatomy of High-Performance Matrix Multiplication.** ACM TOMS, 2008.
- F. Van Zee and R. van de Geijn. **BLIS: A Framework for Rapidly Instantiating BLAS Functionality.** ACM TOMS, 2015.
- T. Smith et al. **Anatomy of High-Performance Many-Threaded Matrix Multiplication.** IPDPS 2014.
- J. Huang et al. **Strassen's Algorithm Reloaded.** SC'16
- https://github.com/flame/how-to-optimize-gemm/wiki
- https://github.com/flame/blislab
- E. Chan et al. **Collective communication: theory, practice, and experience.** C&C:P&E, 2007.
- M. Schatz et al. **Parallel Matrix Multiplication: A Systematic Journey.** SISC, 2016.

Challenges

- Funding
- Access to interesting architectures
- Keeping our sanity

Summary

- MOOCs are a way for us to reach a broad audience.
- Benefits?
  - Open source, open platform, open education, open HPC?
  - Crowd source optimizing DLA?
  - Demonstrate broad impact to funders!
- Can they democratize HPC?

Are we Crazy?

Acknowledgments

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- Partially funded by
  - Second NSF SSI grant
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  - Profit sharing with edX

(LAFF-On) Programming for HPC
- Partially funded by
  - NSF grant on Strassen's algorithm
  - …