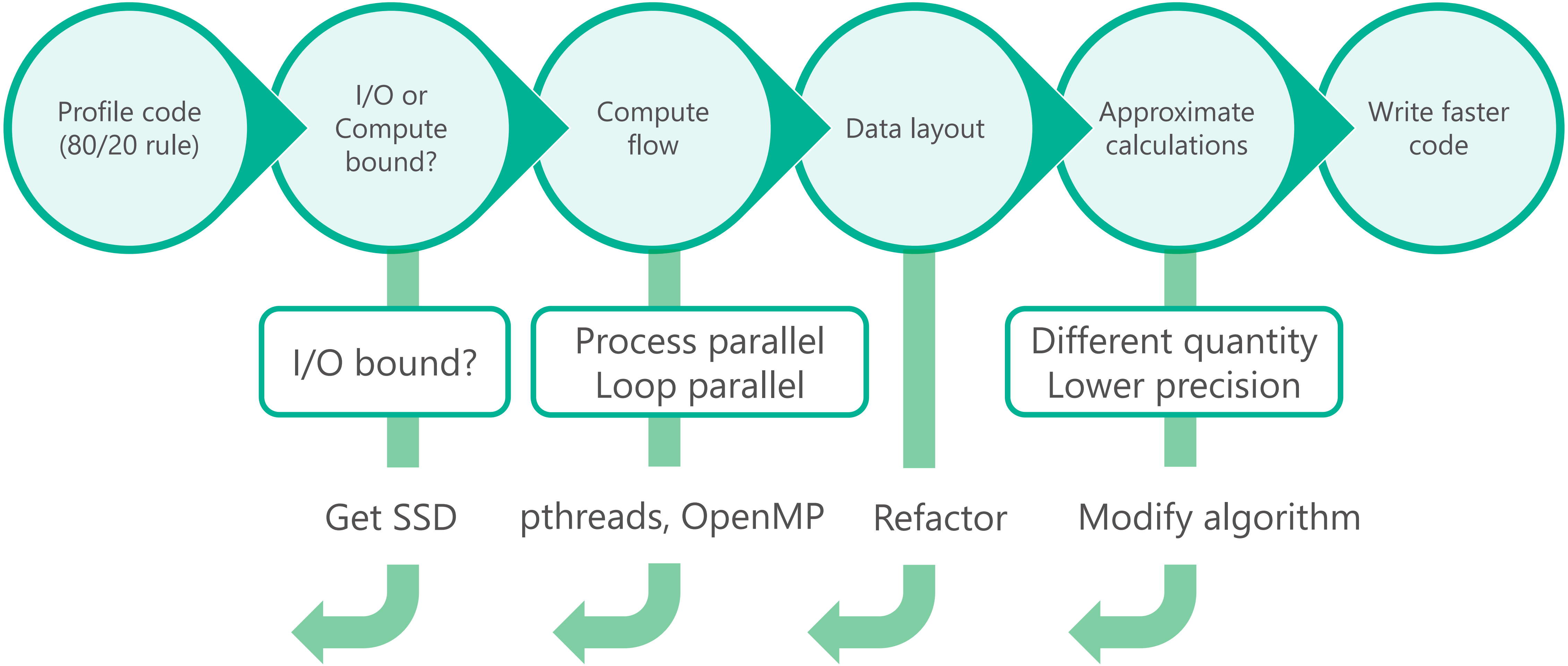
Microsoft Research

Microsoft

Fast code with just enough effort

Pashmina Cameron

Low hanging fruit



Understanding data layout

Data layout

```
struct Point {
        float x;
        float y;
        float feature[M];
};

std::vector<Point> pts;
```

```
struct Point {
        float x;
        float y;
};
struct Feature {
        float feat[M];
};
// parallel vectors
std::vector<Point> pts;
std::vector<Feature> ptFeatures;
```

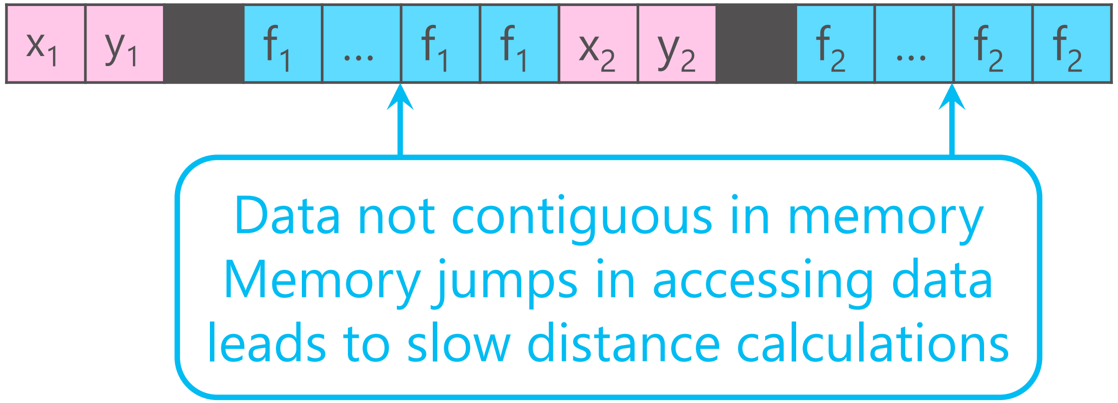
Data layout

```
struct Point {
	float x;
	float y;
	float metadata[N];
	float feature[M];
};

std::vector<Point> pts;
```

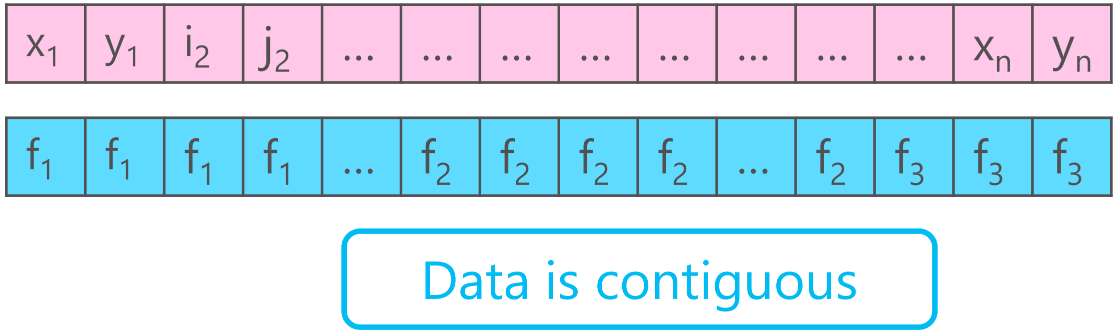
```
struct Point {
	float x;
	float y;
	float metadata[N];
};
struct Feature {
	float feature[M];
};
// parallel vectors
std::vector<Point> pts;
std::vector<Feature> ptFeatures;
```

Data layout

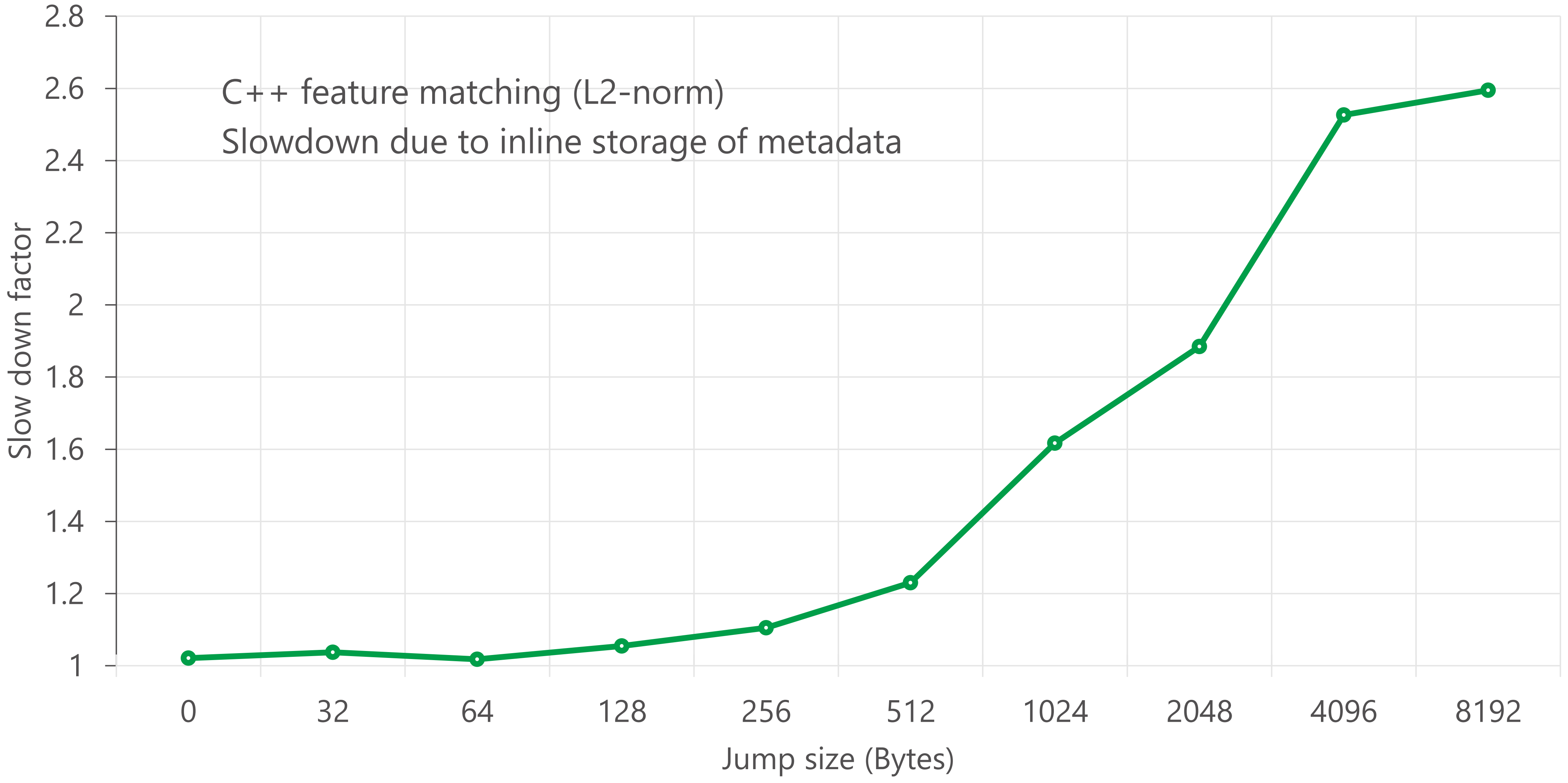
```
struct Point {
        float x;
        float y;
        float metadata[N];
        float feature[M];
};

std::vector<Point> pts;
```




```
struct Point {
        float x;
        float y;
        float metadata[N];
};
struct Feature {
        float feature[M];
};
// parallel vectors
std::vector<Point> pts;
std::vector<Feature> ptFeatures;
```



Data layout matters



Understanding language and compiler

Language choice

	Python	C++
Purpose	prototyping	shipping
Constraints	readability time existing software	power memory speed security hardware

A simple benchmark

An algorithm that is

- well-understood
- not domain-specific
- suited to multiple programming languages
- is computationally intensive

Monte Carlo simulations

Kalman filters

Bundle adjustment

Linear least squares

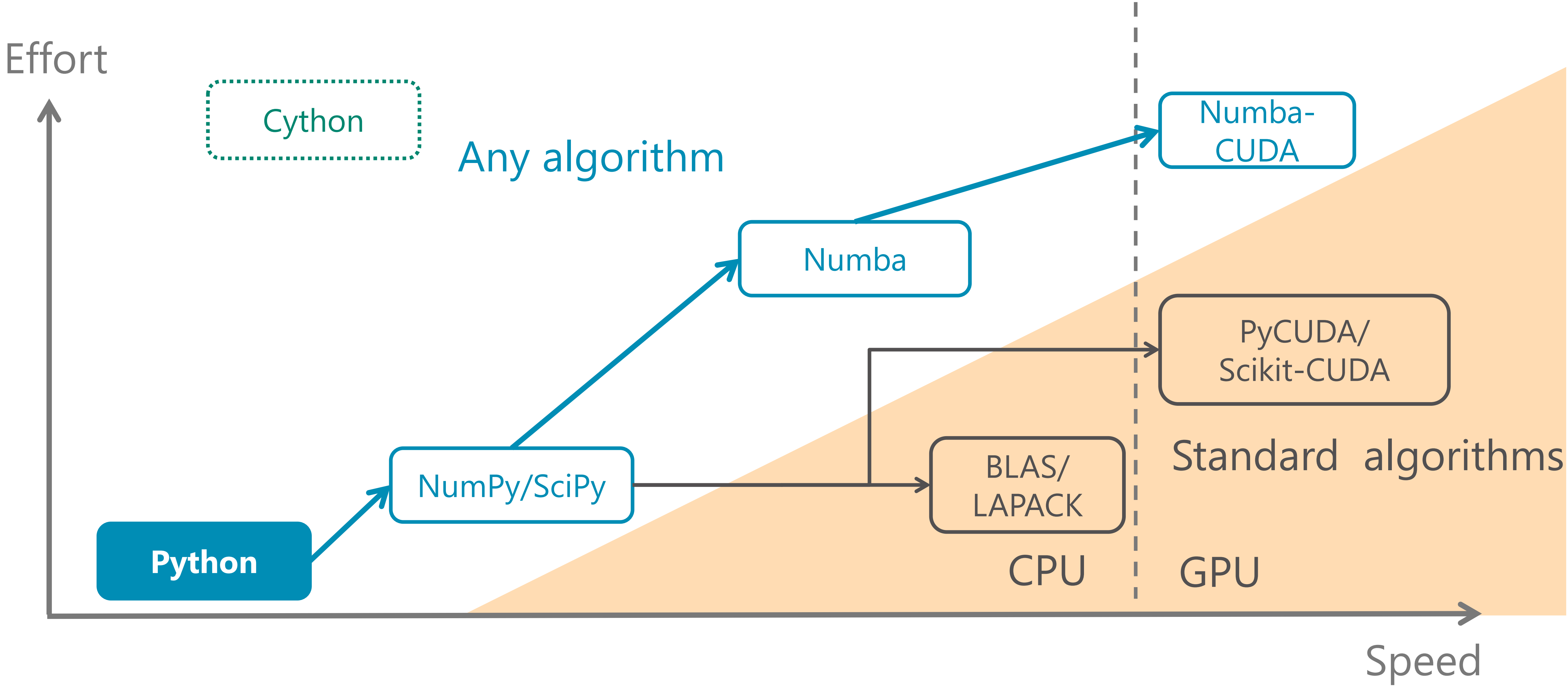
Expectation propagation

Computing Cholesky decomposition of A

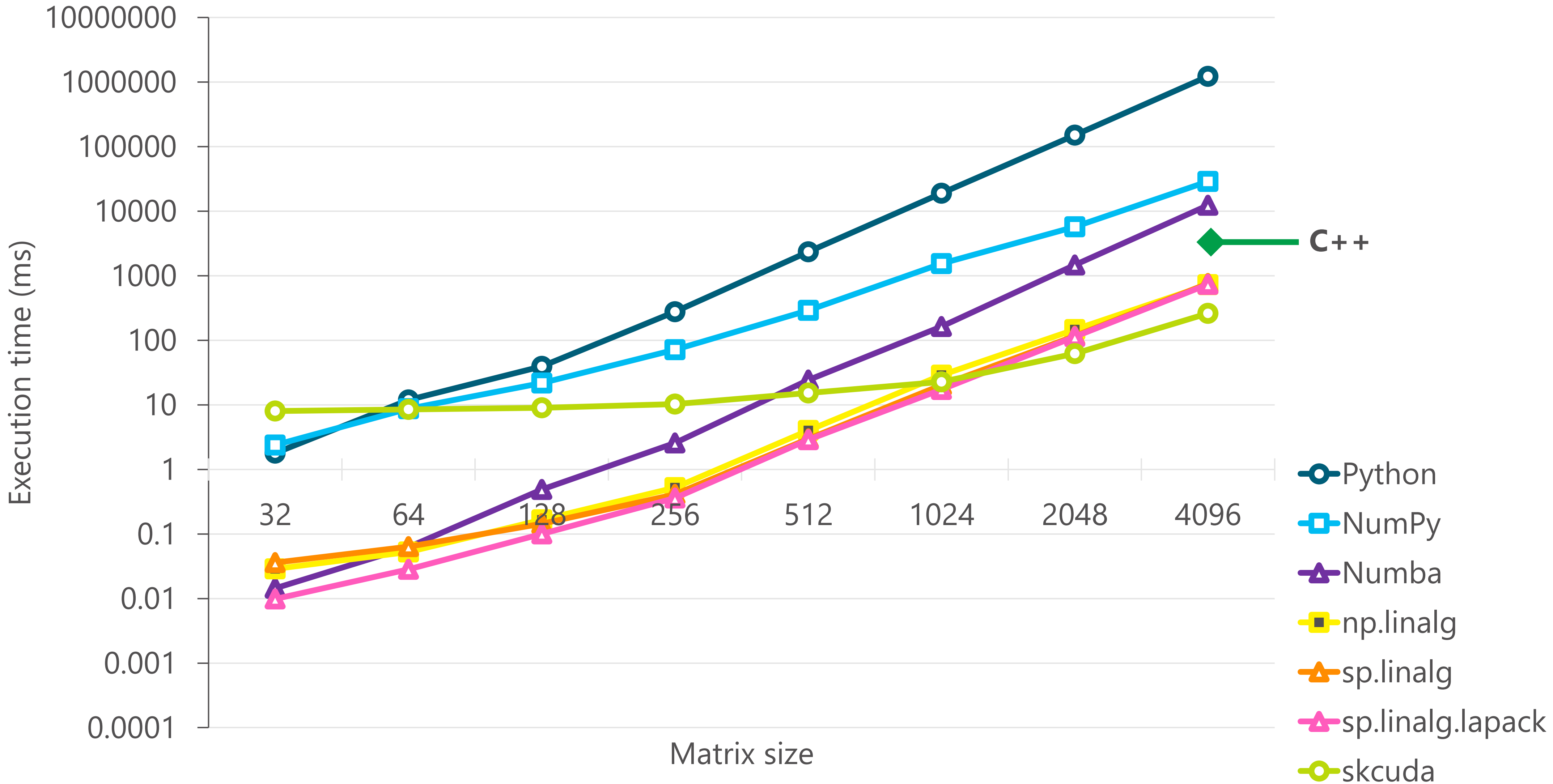
$$A = L L^T$$

simplifies the process of solving $Ax = b$

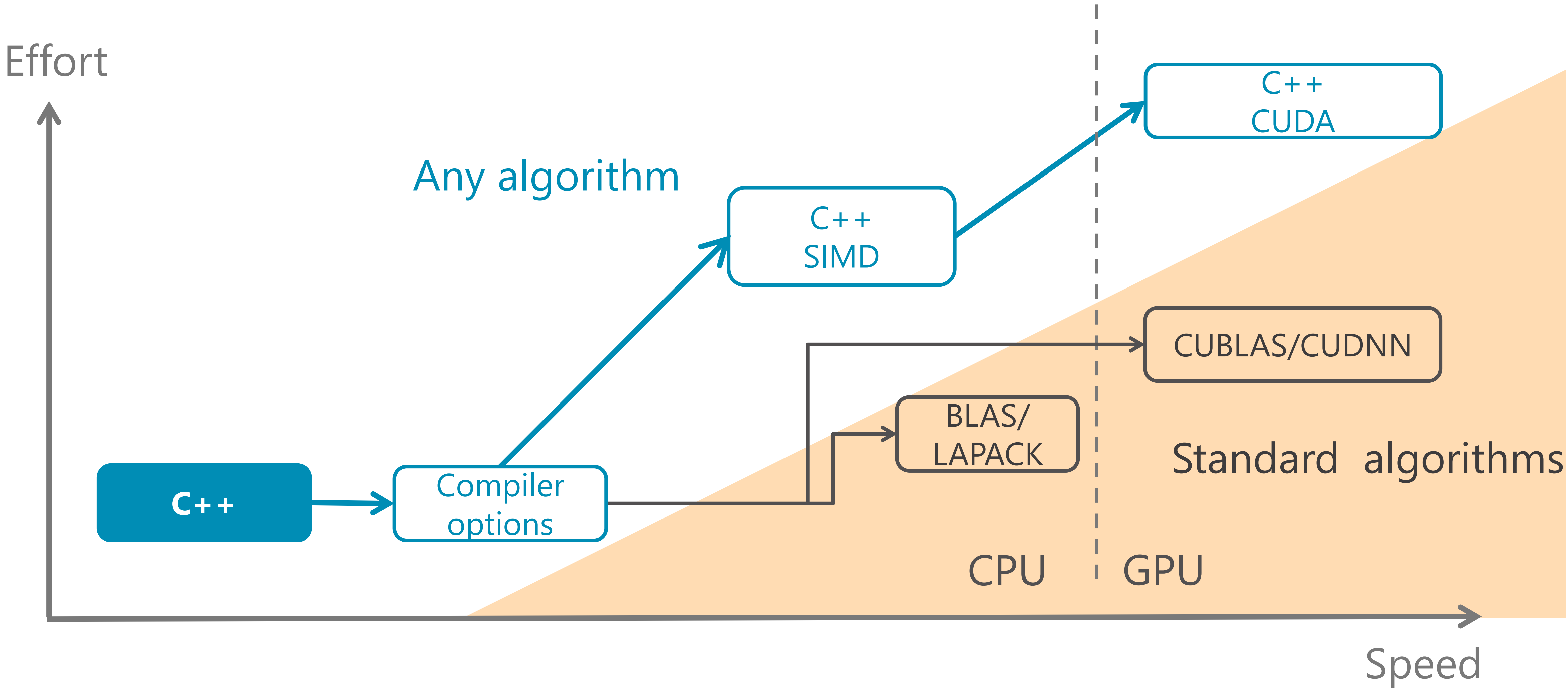
Python


Effort
Cython
Any algorithm
Numba-
CUDA
Numba
PyCUDA/
Scikit-CUDA
Standard algorithms
BLAS/
LAPACK
NumPy/SciPy
Python
CPU
GPU
Speed

Python Cholesky implementations

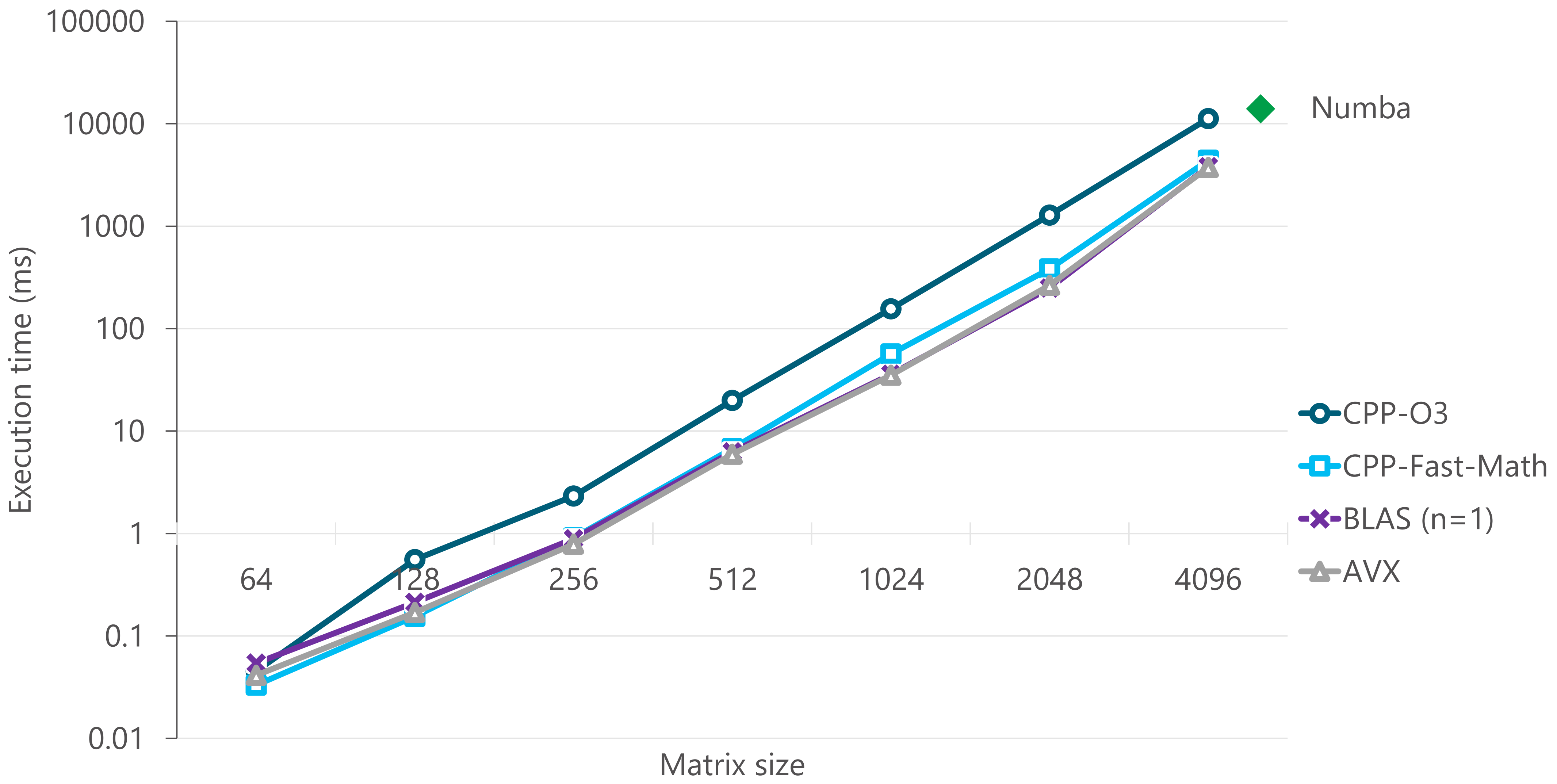


C++

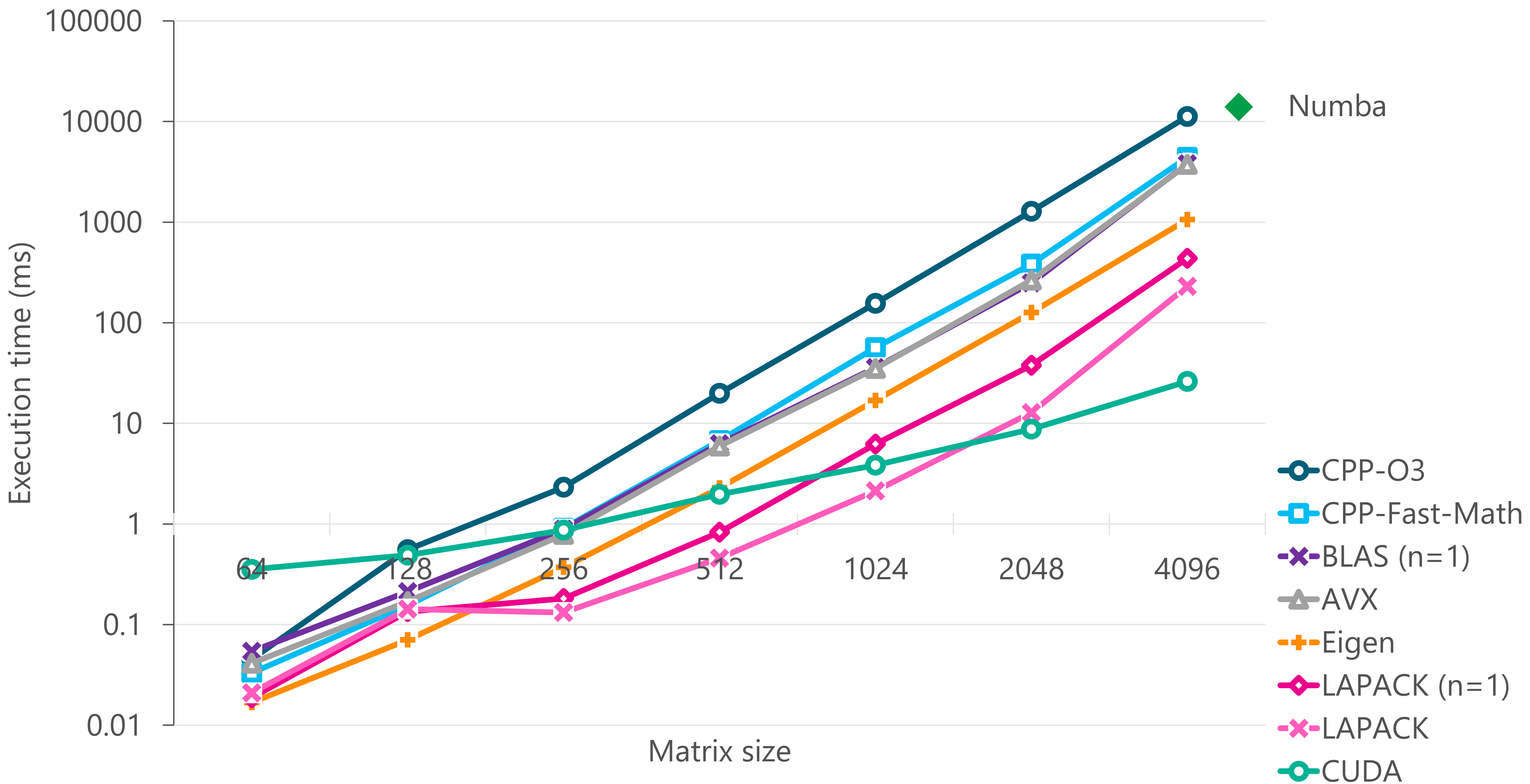


Effort
Any algorithm
C++
SIMD
C++
CUDA
CUBLAS/CUDNN
BLAS/
LAPACK
Standard algorithms
C++
Compiler
options
CPU
GPU
Speed

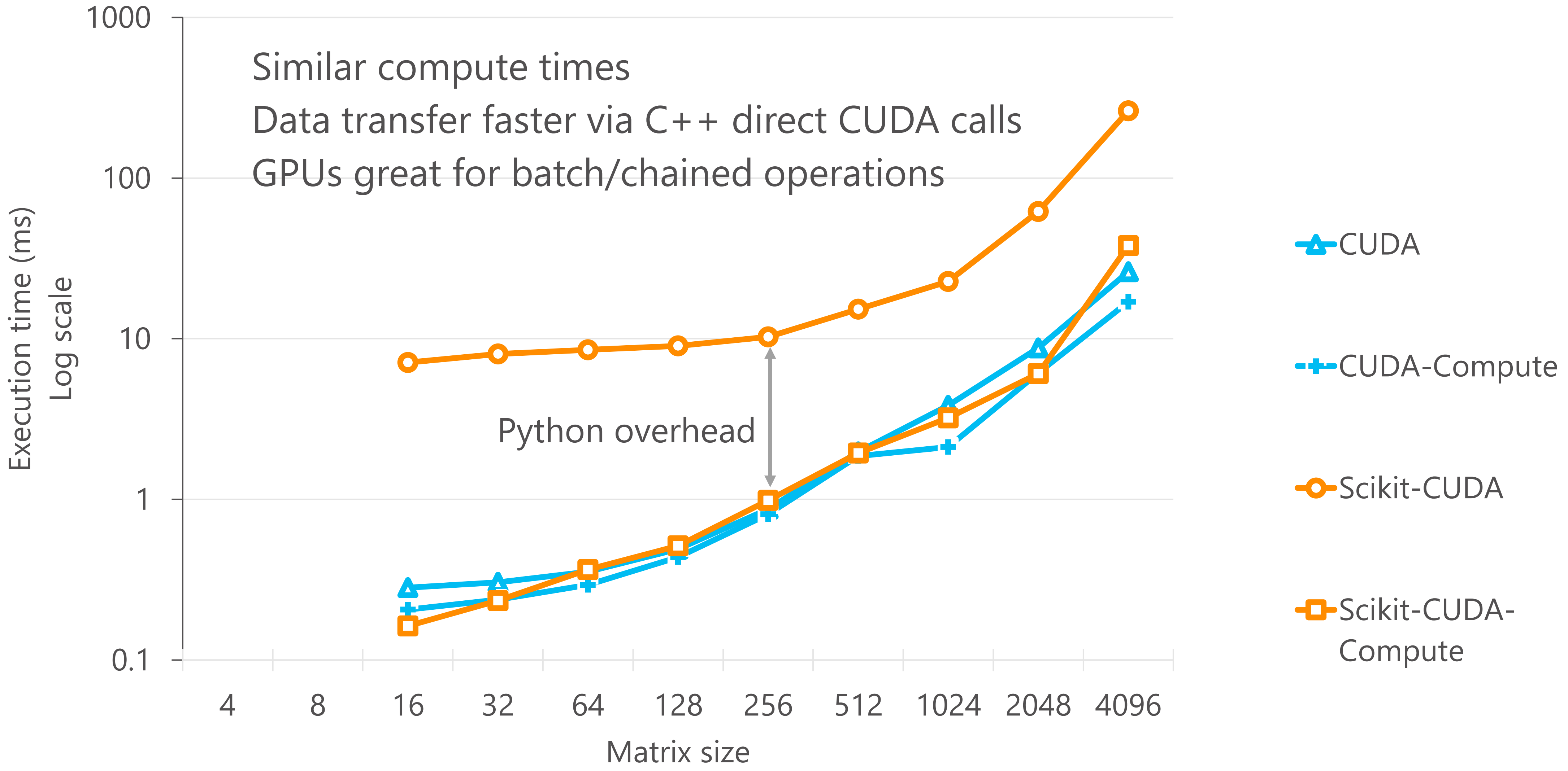
C++ Cholesky implementations ($M = L L^T$)



C++ Cholesky implementations ($M = L L^T$)



Using CUDA from Python vs C++



Harnessing domain knowledge

Using domain knowledge

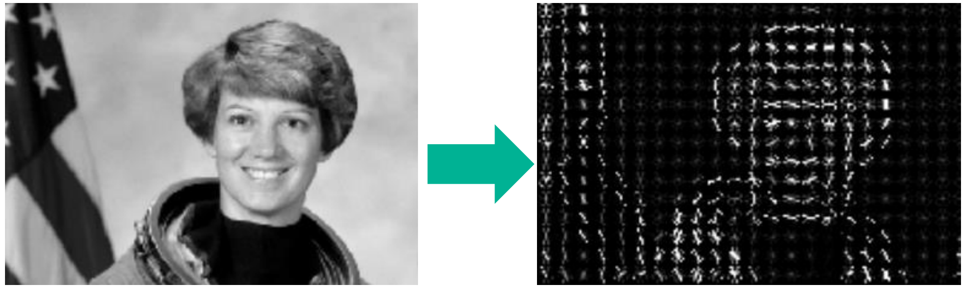


Image courtesy of scikit-cuda docs

Algorithm

- Compute gradients
- Bin gradients into orientation bins
- PopCount on spatial distribution
- Form a feature vector
- L2 norm to match features

Tricks

- Use uint8_t or fixed point to store features instead of floats
- Approximate magnitude (53*min(dx,dy))>>7 + max(dx,dy)
- Use 8 bins and use bit comparison instructions for binning instead of nested branching
- Store distances with 2x precision

4x less storage

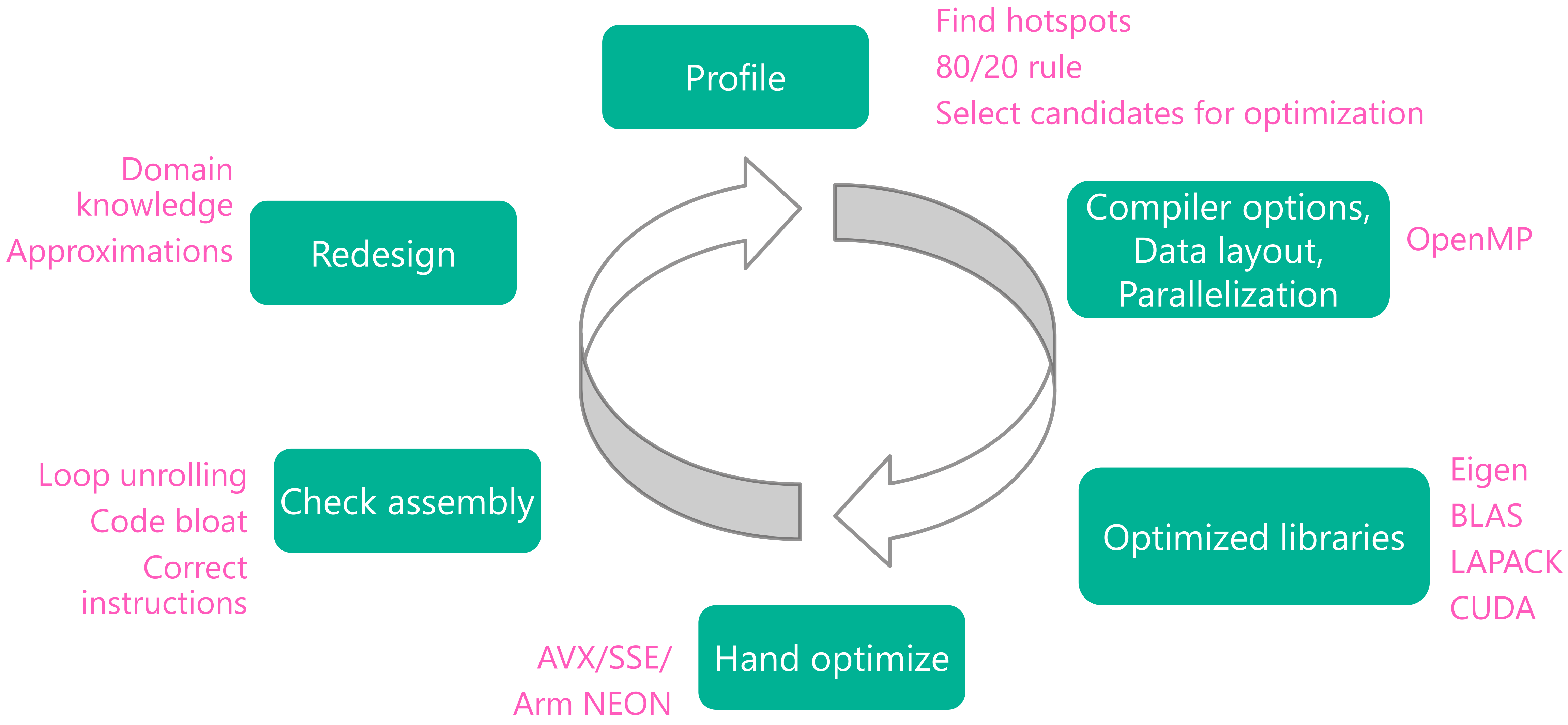
8-12x faster feature computation

64x faster feature matching

Dalal and Triggs, HOG, CVPR 2005

David Lowe, SIFT, IJCV 2004

C++ optimization cycle

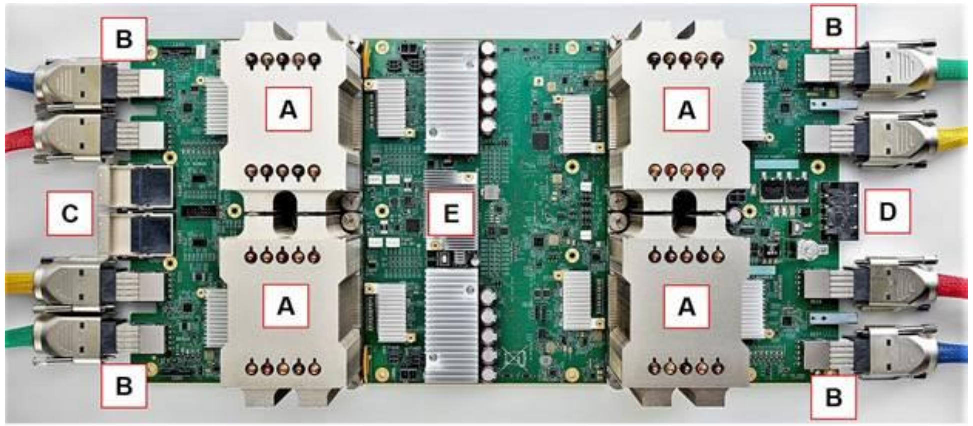


When everything else fails….

End of general purpose H/W

Co-designing software and hardware is the future

Domain specific hardware aims to do just that.

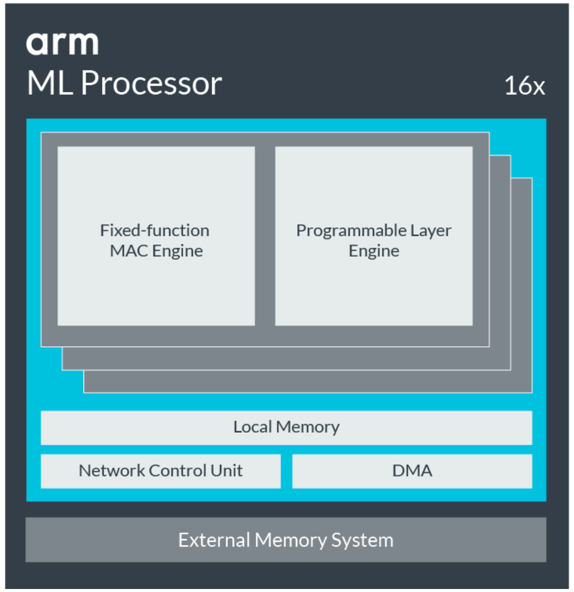


Google TPU

Intel Xeon FPGA

Intel Movidius NCS

Microsoft Catapult



ARM ML Processor

Images from company web pages/press releases

Thank you for listening

Blog:
https://pashminacameron.github.io/

Code:
github.com/pashminacameron/cholesky_benchmarking

Contact:
pashmina.cameron@microsoft.com