EECS
Electrical Engineering and Computer Sciences

Productive Auto-tuning of Stencil Grid Kernels

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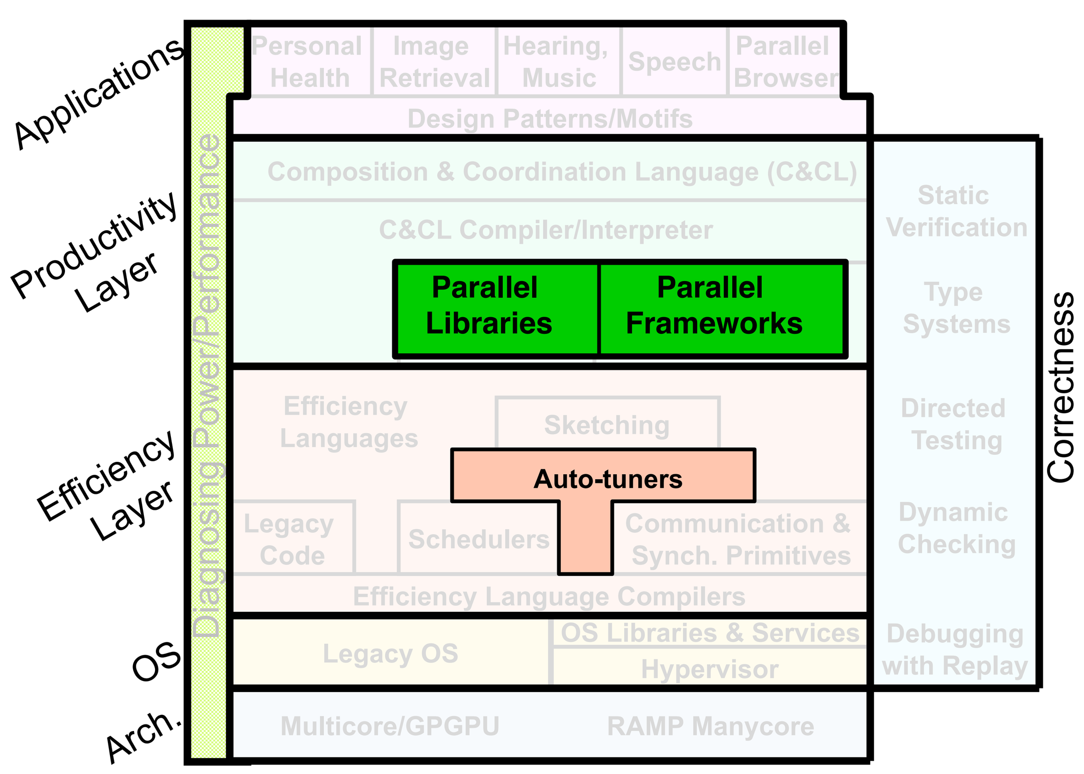
PARALLEL COMPUTING LABORATORY

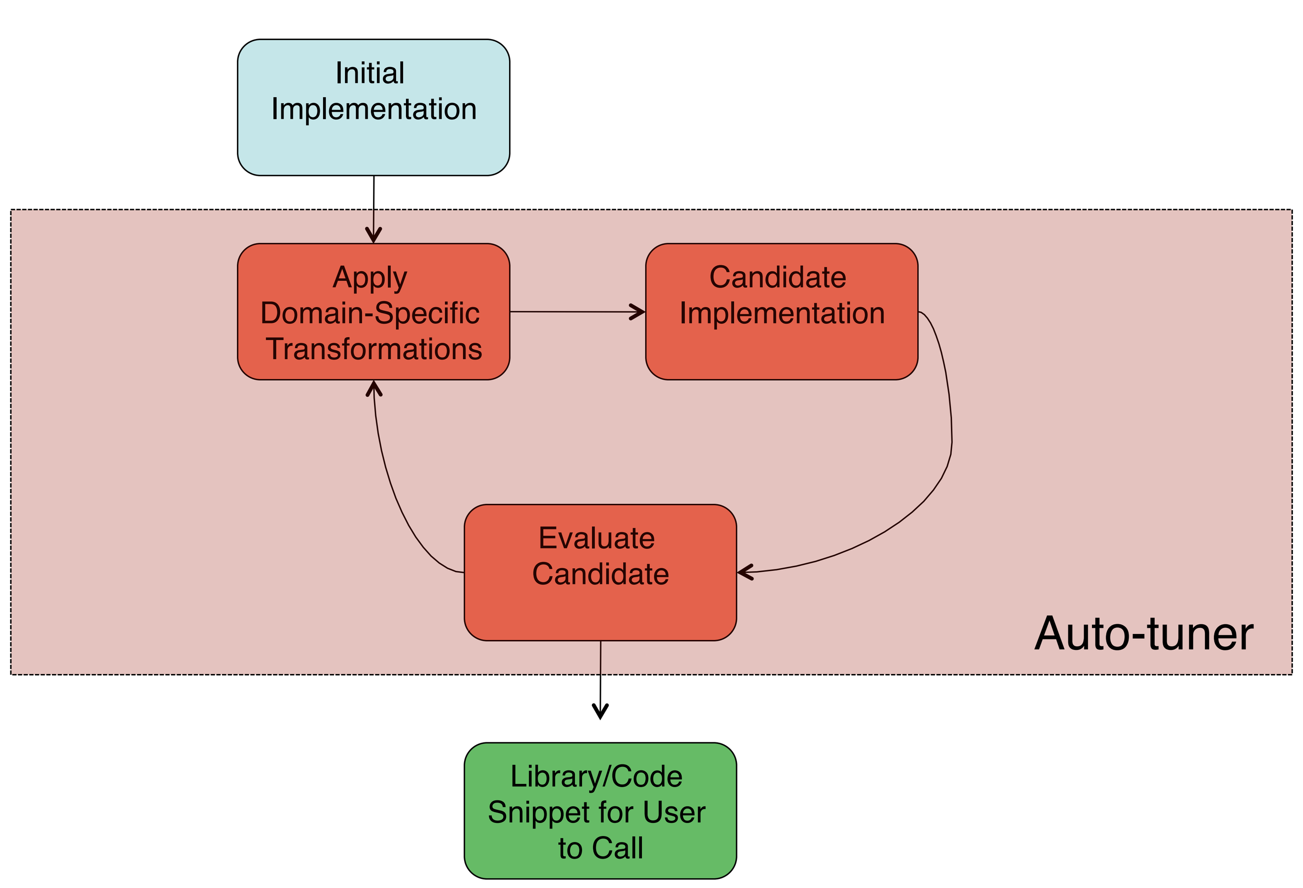
Where this fits in the ParLab

- ParLab is the interdisciplinary group at UC Berkeley investigating the impact of many-core parallelism
- Software stack is divided into Efficiency and Productivity Layers
- This work crosses between both layers, providing framework/library support for arbitrary structured grid kernels



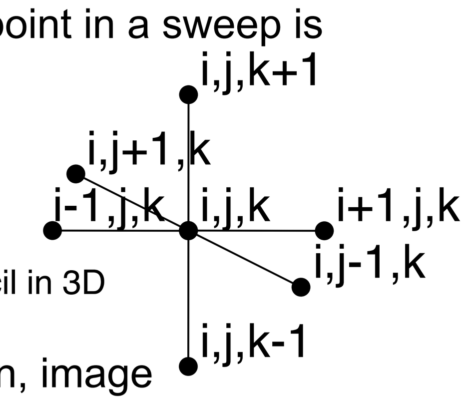
Productive Auto-Tuning

- Auto-tuning is an automated, general system for performance portability across architectures, using domain-specific knowledge
- Traditional optimization speeds up **one** kernel on **one** platform
- Traditional Auto-tuning speeds up **one** kernel on **many** platforms
  - Strategy in many numerical libraries such as Atlas and OSKI
- Productive Auto-tuning: goal is to speed up **many** kernels on **many** platforms
  - Build tuner for a *class* of kernels
  - Use high-level knowledge of the motif to optimize specific instantiations



Structured Grid: Stencil Kernels

- Many computations on grids with regular structures can be represented as "sweeps" over the grid, where each point in a sweep is a arithmetic combination of the point's neighbors

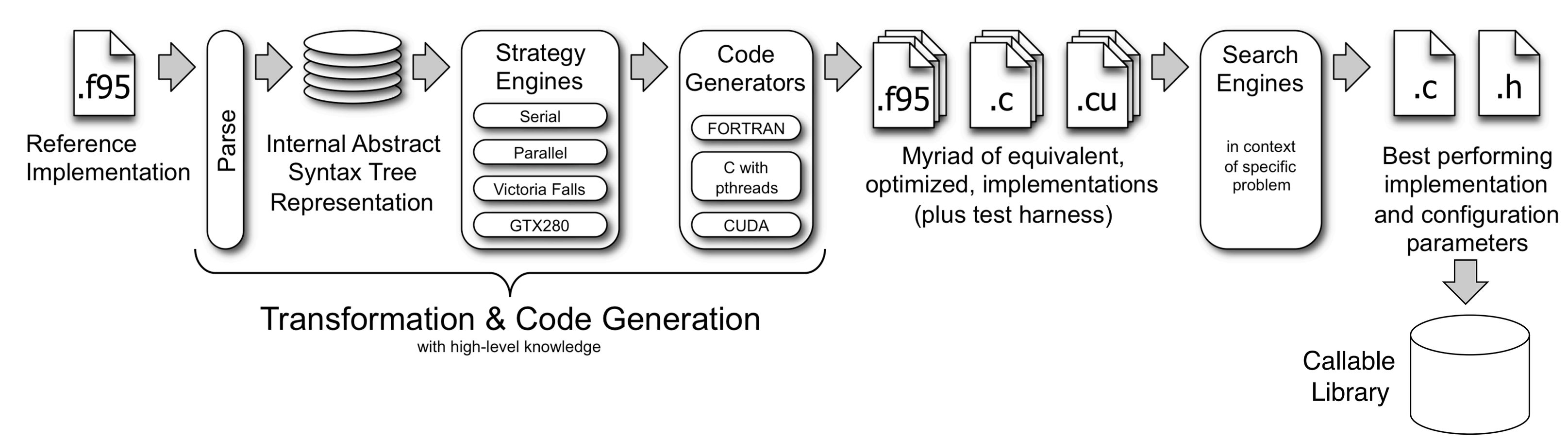


Example: 7 point stencil in 3D

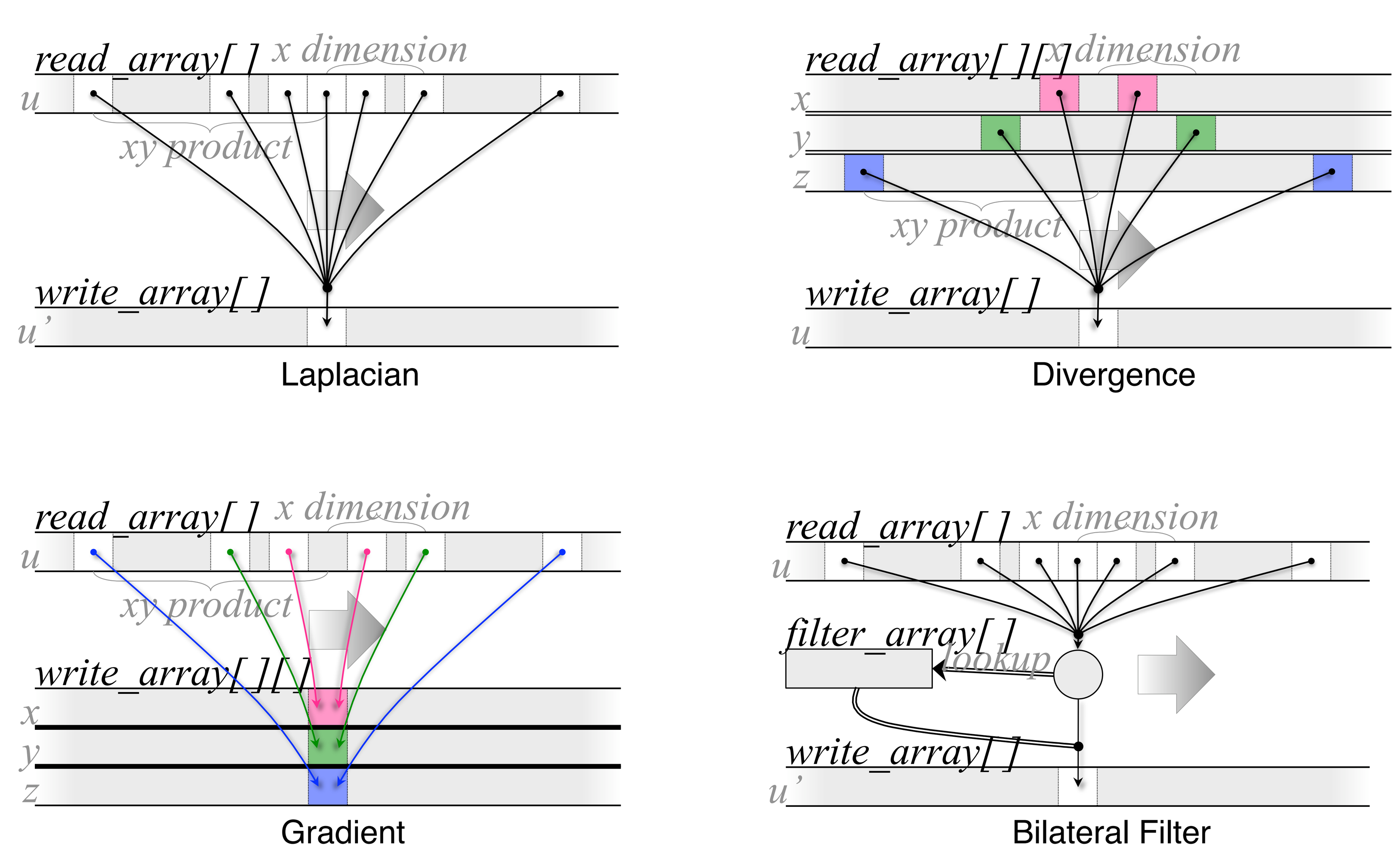
- Applications include PDE solvers, climate simulation, image processing/filtering

Auto-tuner Design

- Stencils described in a Domain-Specific Language (DSL)
  - Currently a simple subset of Fortran
- Auto-tuner takes annotated description of kernel and performs the following steps:
  1. Auto-tuner parses stencil code into an intermediate representation
  2. Representation is transformed into auto-parallelized version
  3. Backend strategy engines enumerate applicable parameter space and
     1. Generate timing stub
     2. Generate each version of code
     3. Iterate over versions & measure performance
     4. Choose optimal version
  4. Best-performing version is packaged into callable library

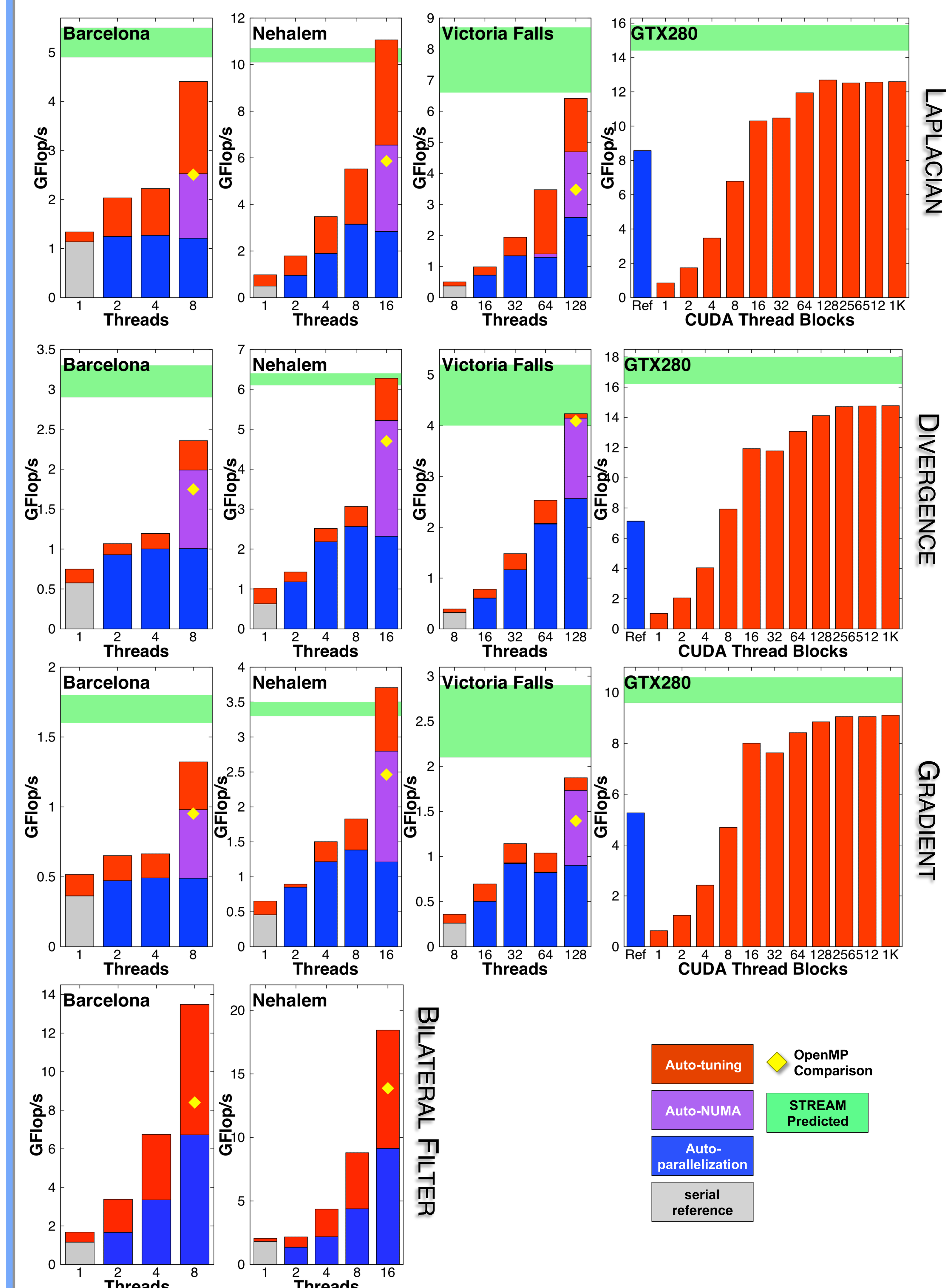


Example Stencil Kernels



- Original Fortran code uses multidimensional arrays
- Auto-tuned C code uses flat single-dimensional arrays
- Bilateral filter has *radius* parameter that changes stencil footprint

Performance Results



- Excellent performance gains
  - Up to 22x for memory-bound kernels
  - Near-perfect scaling for compute-bound bilateral filter kernel
  - Comparable to kernel-specific auto-tuning performance on multicore from previous work
- Productivity gains: Performance and Kernel portability
  - Laplacian, Divergence, and Gradient tuned fully-automatically
  - Required no changes to auto-tuning framework
  - Compared to auto-tuning each kernel individually: large portion of performance at a fraction of the effort
    - Hand-tuner for a single kernel requires weeks to months of effort!
- Lots of future work
  - Extend generality of supported kernels (and define the domain)
  - Improve CUDA/OpenCL tuner to incorporate better optimizations
  - Extend supported backends (Local store archs, etc.)
  - Friendly frontend: also support higher-level definitions of kernels