EasyPAP: a Framework for Learning Parallel Programming

Alice Lasserre, Raymond Namyst, Pierre-André Wacrenier
firstname.lastname@u-bordeaux.fr

Dept. of Computer Science

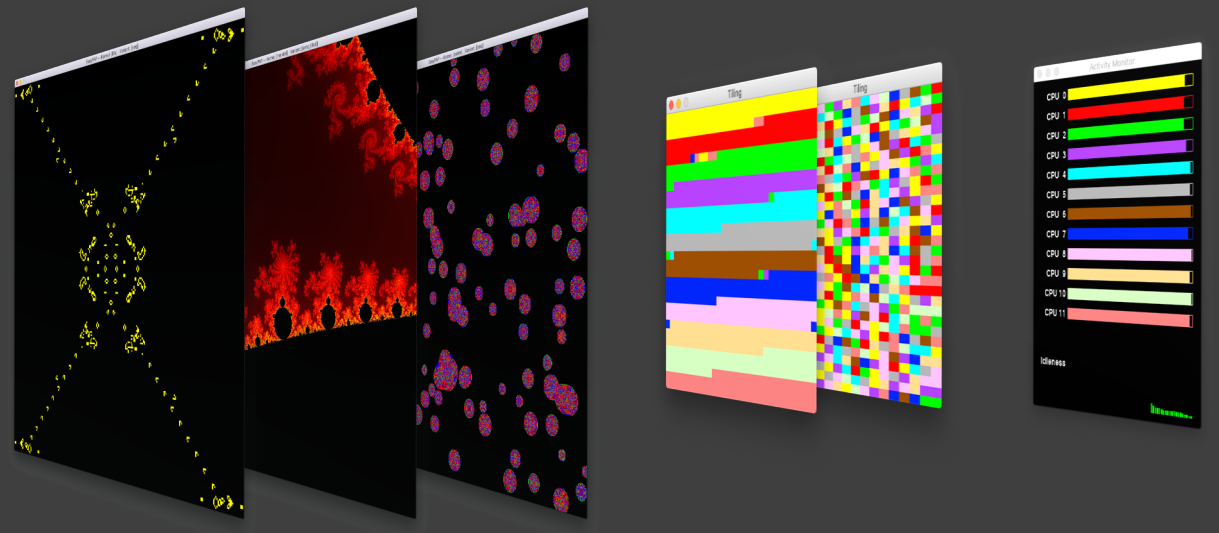
université de BORDEAUX

A case for a comprehensive framework

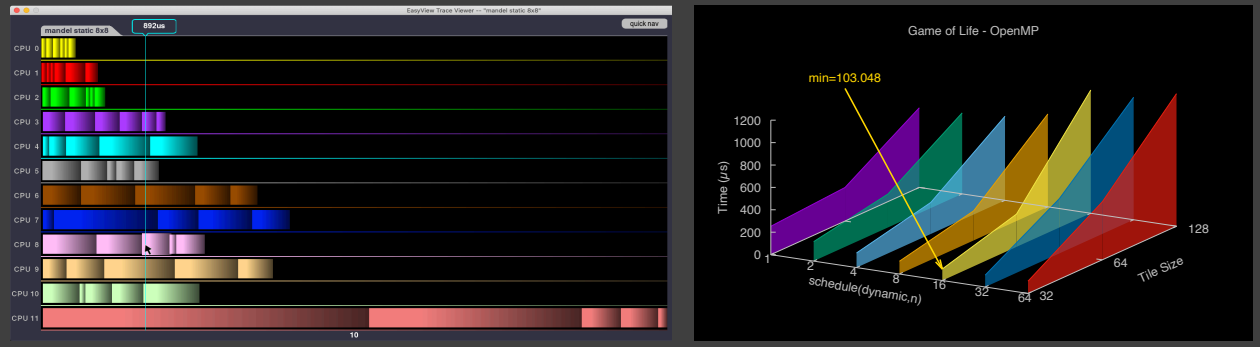
- Parallel programming is not trivial
  - Debugging is entering a world of pain
  - Understanding (bad) performance is even more challenging
- Like many teachers, we progressively added visualization facilities to our lab applications
  - Increased student's motivation
  - Greatly helped to improve correctness
- EasyPAP goes further
  - Minimize time spent to become familiar with new problems
  - Enable quick OpenMP/MPI/OpenCL prototyping
  - Provide simple tools to analyze parallel behavior

EasyPAP: focus on parallelism!

- C library + utilities
  - Support for Pthreads, OpenMP, MPI, OpenCL
- Online rendering of 2D computations
  - Work distribution monitoring
- Trace visualization
  - Side-by-side comparison
- Plotting facilities
  - Thorough experiments & analysis



Online visualization and thread monitoring



Offline trace visualization and plotting facilities

Kernels and variants

- Students are provided with sequential implementations of various *kernels*
  - Mandelbrot Set, Game of Life, Abelian Sandpiles, Picture Blur
  - ✓ Just add a C file to create a new kernel, then compile & run
- They can design and experiment with as many *variants* as they can think of
  - Kernels and variants are selected on command line
  - ✓ Just add a function to create a new variant, then compile & run

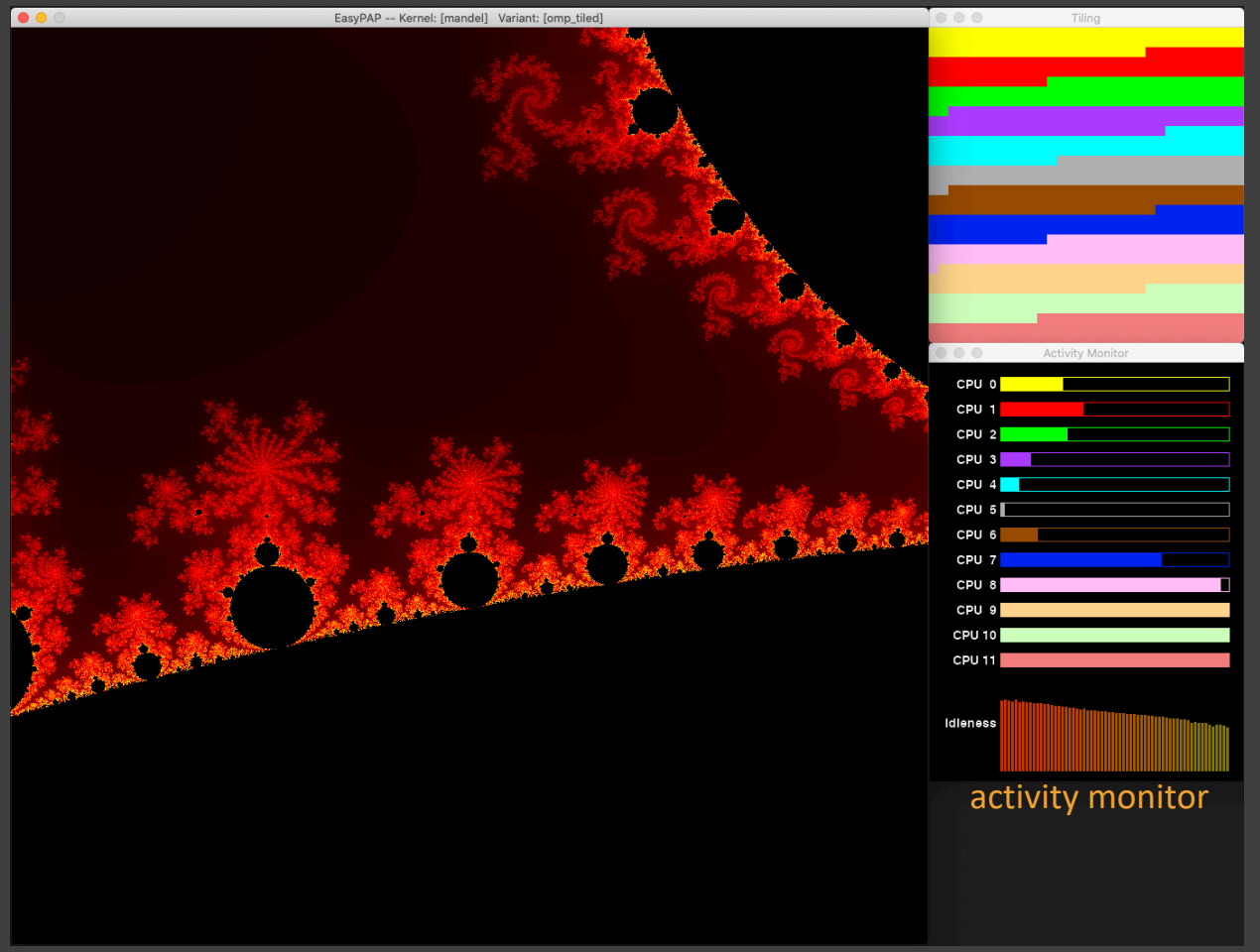
```
///////////////////////////// Simple sequential version (seq)
// Suggested cmdline:
// easypap --kernel mandelset --variant seq
//
unsigned mandelset_compute_seq (unsigned nb_iter)
{
  for (unsigned it = 1; it <= nb_iter; it++) {
    for (int y = 0; y < DIM; y++)
      for (int x = 0; x < DIM; x++)
        cur_img (y, x) = compute_one_pixel (y, x);

    zoom ();
  }
  return 0;
}

unsigned mandelset_compute_omp (unsigned nb_iter) { }

unsigned mandelset_compute_omp_tiled (unsigned nb_iter) { }

unsigned mandelset_compute_mpi (unsigned nb_iter) { }
```

Code instrumentation and monitoring

```
// Tile inner computation
static inline void do_tile (int x, int y, int width, int height, int thread)
{
  monitoring_start_tile (thread);
  for (int i = y; i < y + height; i++)
    for (int j = x; j < x + width; j++)
      cur_img (i, j) = compute_one_pixel (i, j);
  monitoring_end_tile (x, y, width, height, thread);
}
///////////////// Tiled OpenMP version (omp_tiled)
// Suggested cmdline: easypap -k mandelset -v omp_tiled -ts 32 -m
unsigned mandelset_compute_omp_tiled (unsigned nb_iter)
{
  for (unsigned it = 1; it <= nb_iter; it++) {
#pragma omp parallel for collapse(2) schedule(runtime)
    for (int y = 0; y < DIM; y += TILE_SIZE)
      for (int x = 0; x < DIM; x += TILE_SIZE)
        do_tile (x, y, TILE_SIZE, TILE_SIZE, omp_get_thread_num ());
    zoom ();
  }
return 0;
}
```

main window

tiling window

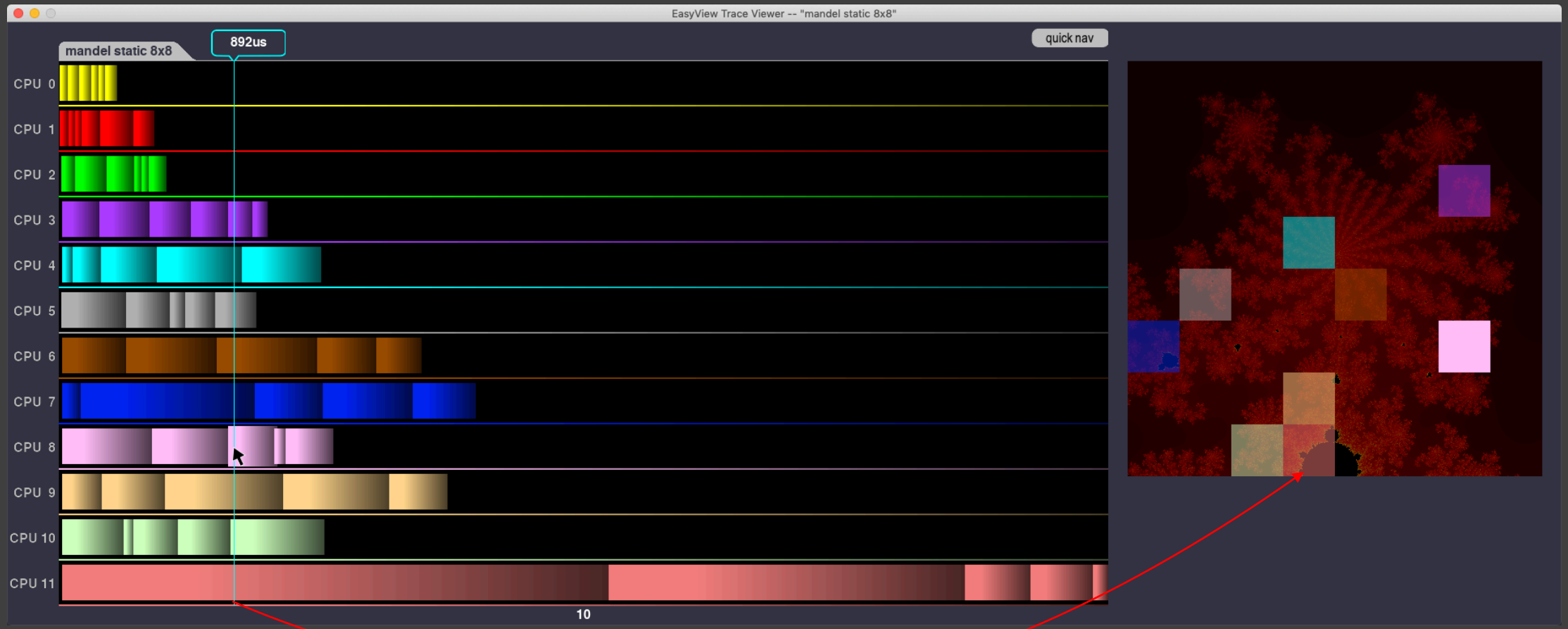


activity monitor

Off-line Trace Visualization

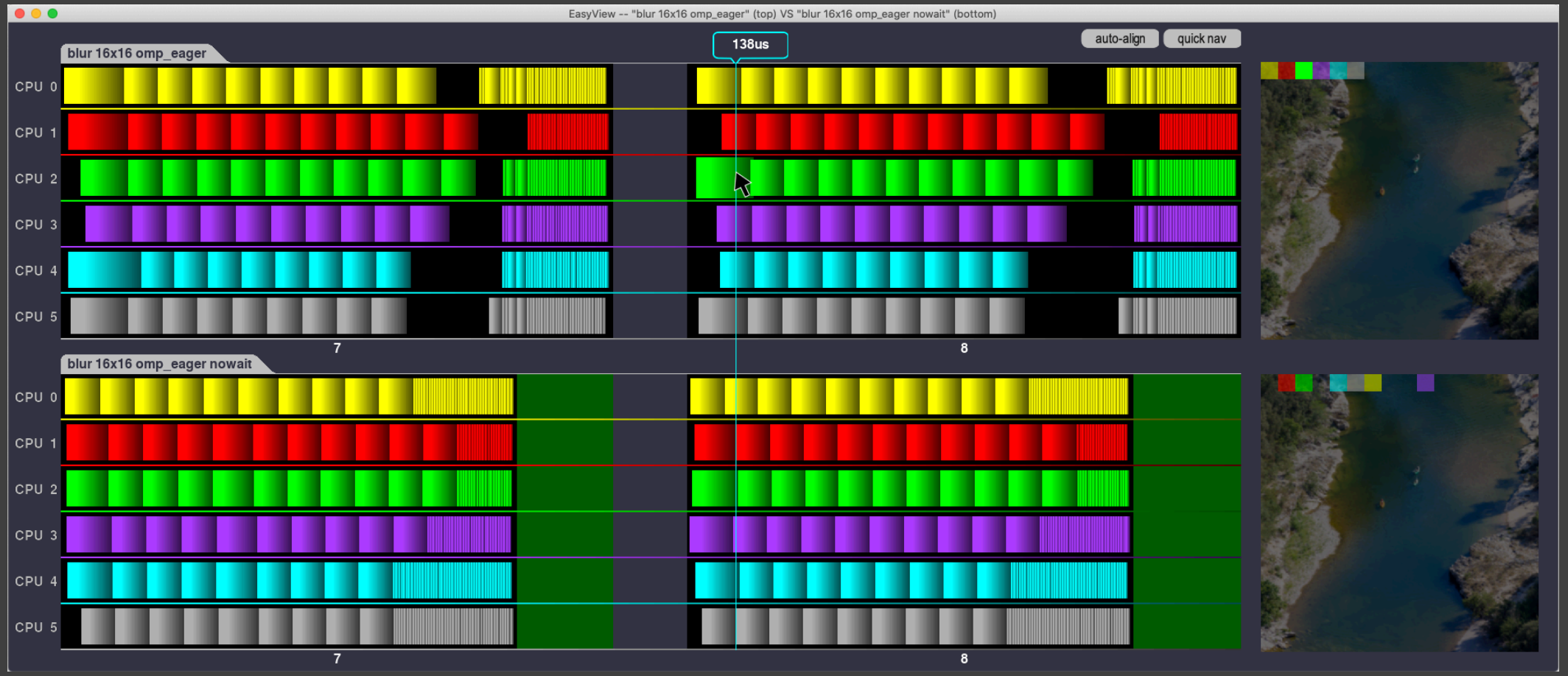
Task scheduling chart

Task-data mapping



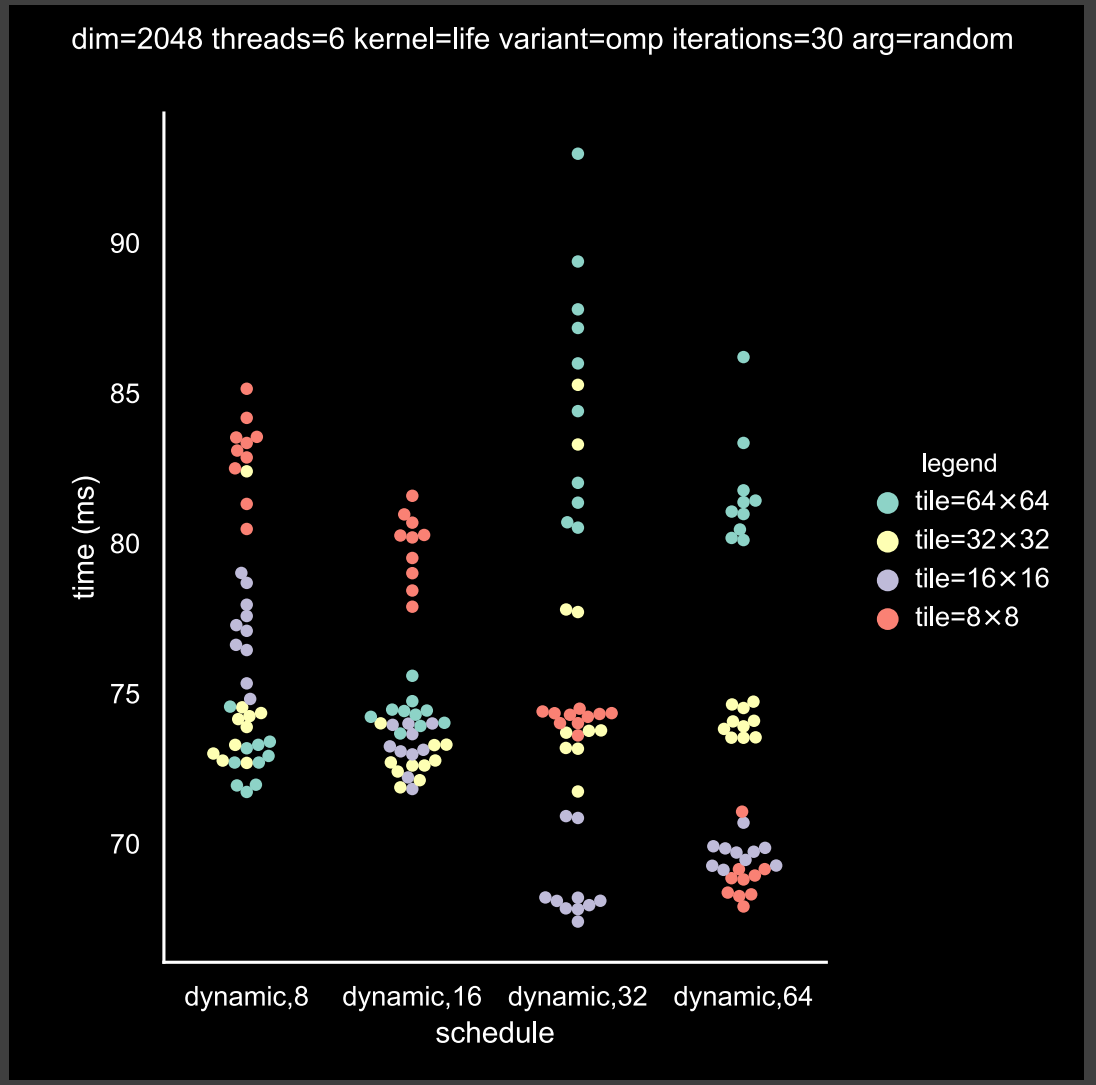
Trace comparison

"diff" mode: iterations are re-aligned



Plotting facilities

- Experiments can easily be automated using scripts
  - No need to recompile
  - Each run records all experimental details in a CSV file
- Plotting (python) scripts
  - Ease graph selection
  - Make sure results are sound
    - Speedups automatically computed
    - Parameter consistency check



What are the main benefits?

- Focus on parallelism
  - Implement many variants
  - Experiments with multiple parameters
- Quicker and deeper understanding of
  - Scheduling
    - Load balancing, data affinity
  - Cache
    - Tiling, false sharing
  - Synchronization
    - Race conditions, barriers, task dependencies
  - Hardware specific optimizations
    - Code specialization, vectorization

CPU coverage map across multiple iterations revealing task-data affinity

EasyPAP documentation and download:

http://gforgeron.gitlab.io/easypap/