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Center for Information Services and High Performance Computing

Detection and Visualization of Performance Variations to Guide Identification of Application Bottlenecks

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Introduction

- Complexity of HPC systems is ever-increasing
- This creates challenges performance analysis

- Analysis techniques with different granularities and goals exist
  - Detailed execution recordings are well-suited for detecting performance variation across processes and/or time

- Automatic problem search ↔ visualization-based analysis

- We provide a new visualization-based approach for detecting performance problems

Introduction

- Assumptions:
  - Processes exhibit similar runtime behavior – SPMD
  - Processes execute the same code repeatedly – iterations

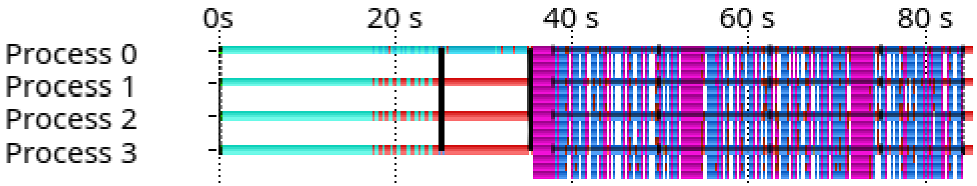
  - The duration of iterations should be similar between processes as well as between iterations on the same process

- If iterations vary in duration, this might indicate a performance problem (runtime imbalance / performance variation)

- Our approach detects such imbalances and highlights iterations with notably higher duration

Introduction

- We use execution traces [1,2] as the basis of analysis
  - Time-stamped events, in particular function enter & exit
- Timeline-based visualizations [3-5]
- Post-mortem analysis



- Approach:
  1. Identify dominant functions
  2. Compare runtime of them across iterations and processes
  3. Visualize these differences

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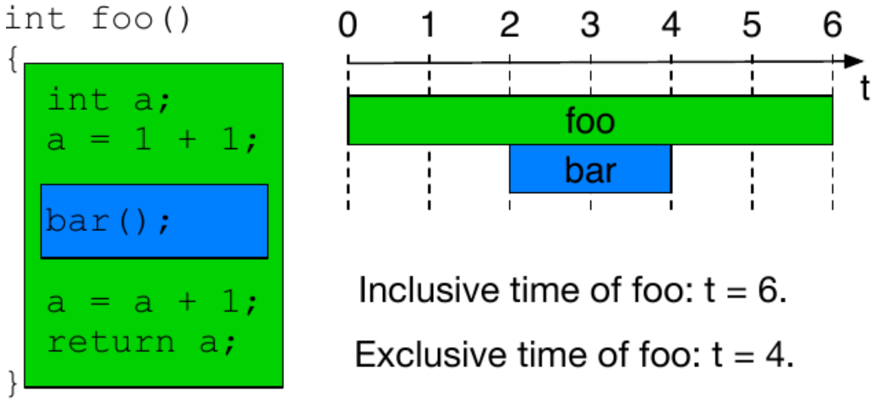
Identify Time-Dominant Functions

- Goal: Identify recurring parts of an application execution to then compare the runtime of these *segments*

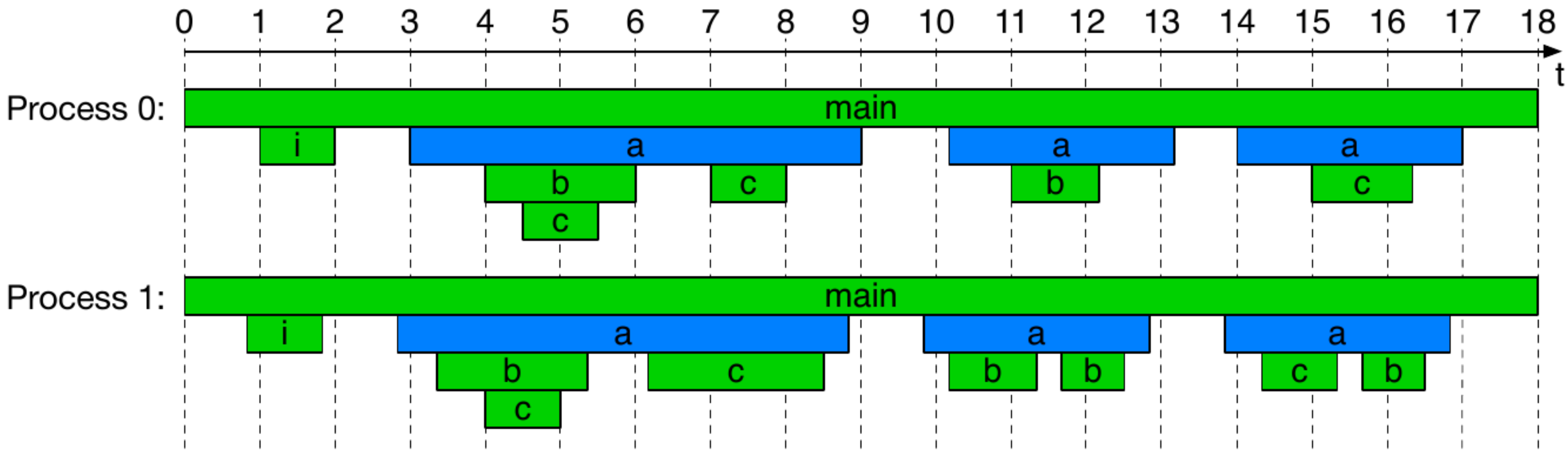
- What are suitable segments?

- Functions with a large inclusive time
  - Inclusive time is the time spent in a function including time spent in subfunctions



Identify Time-Dominant Functions

- Taking the function with just the largest inclusive time doesn‘t work, for example:



- Time-dominant function:= Function with the highest aggregated inclusive time which is called at least 2*p* times, where *p* is the number of processes

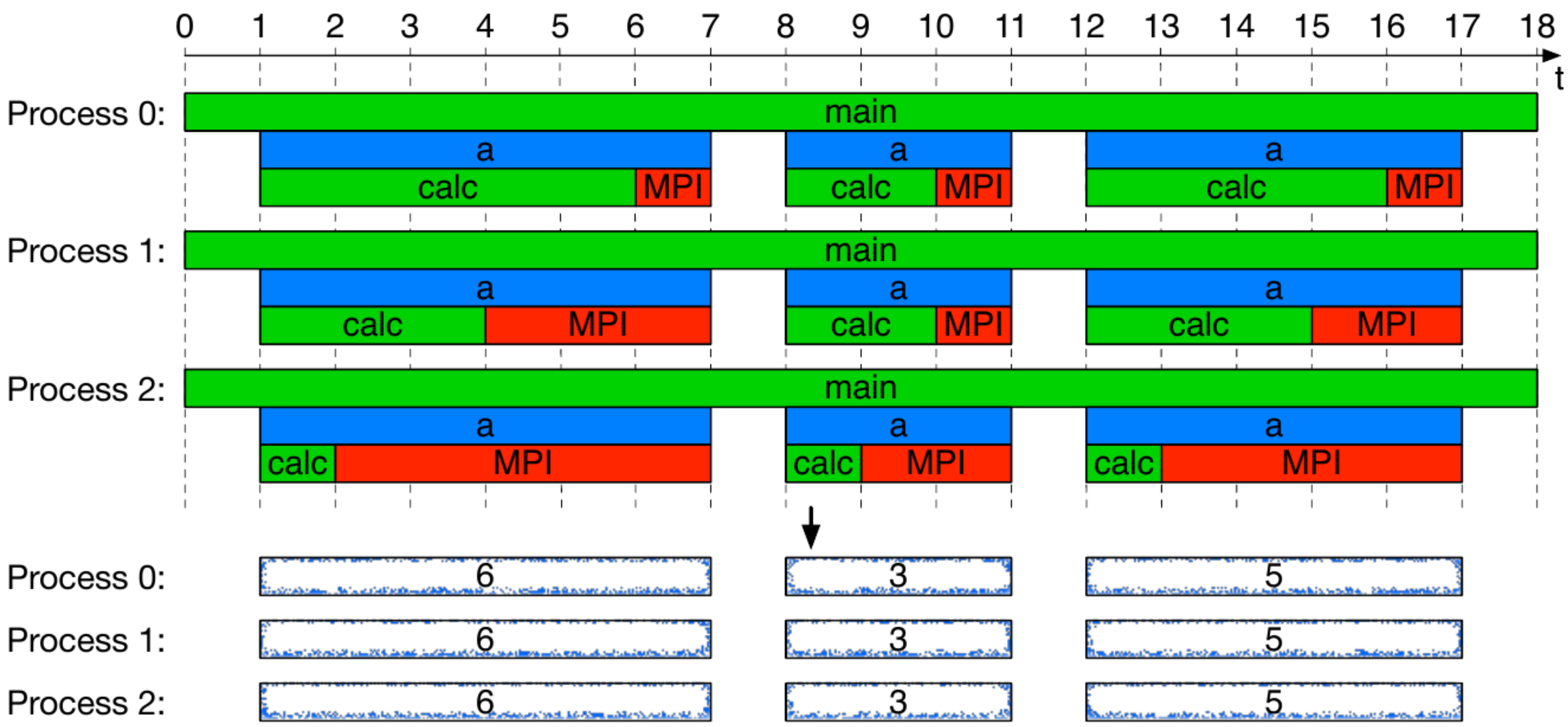
Analyze Runtime Imbalances

- Goal: Detect shifts in execution time of segments

- Assumptions:
  - If an application slows down, likely the time-dominant function runs longer
  - Outlier behavior likely impacts the runtime of the time-dominant function

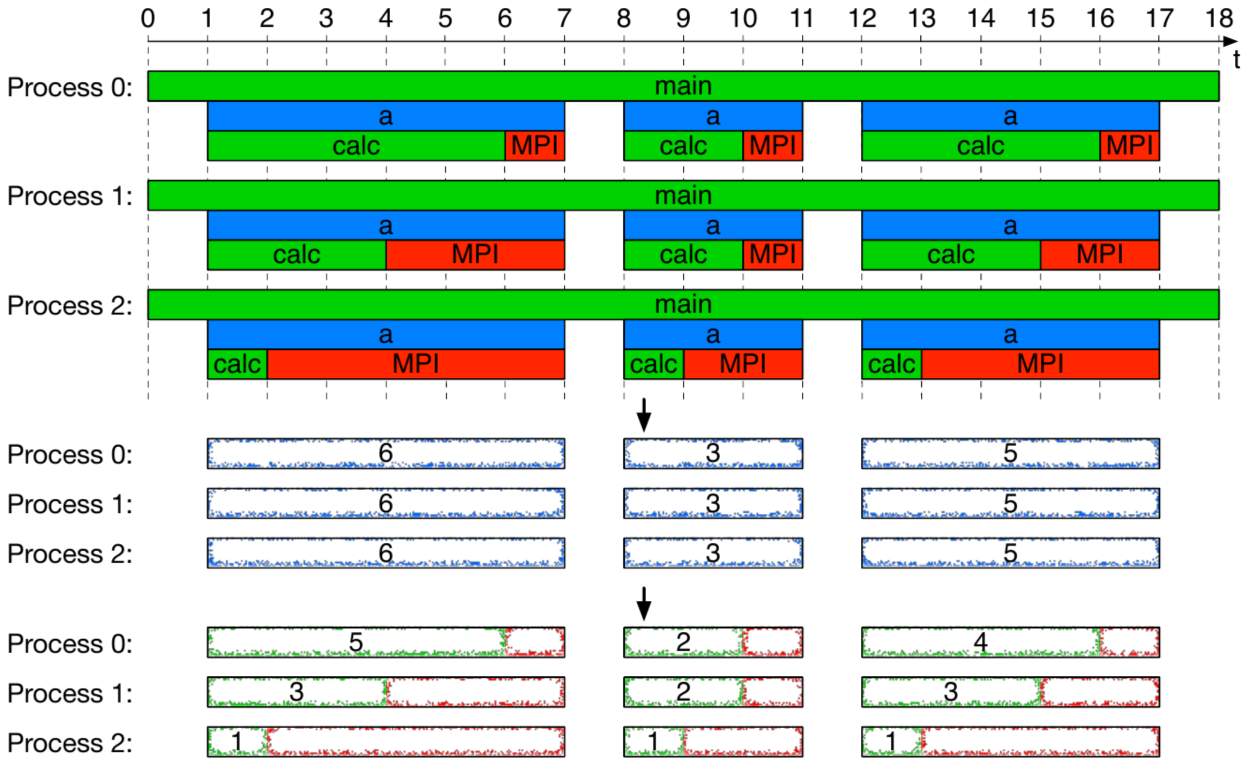
Analyze Runtime Imbalances

- Directly comparing segments has a shortcoming:
  - Included Communication time can even out variations



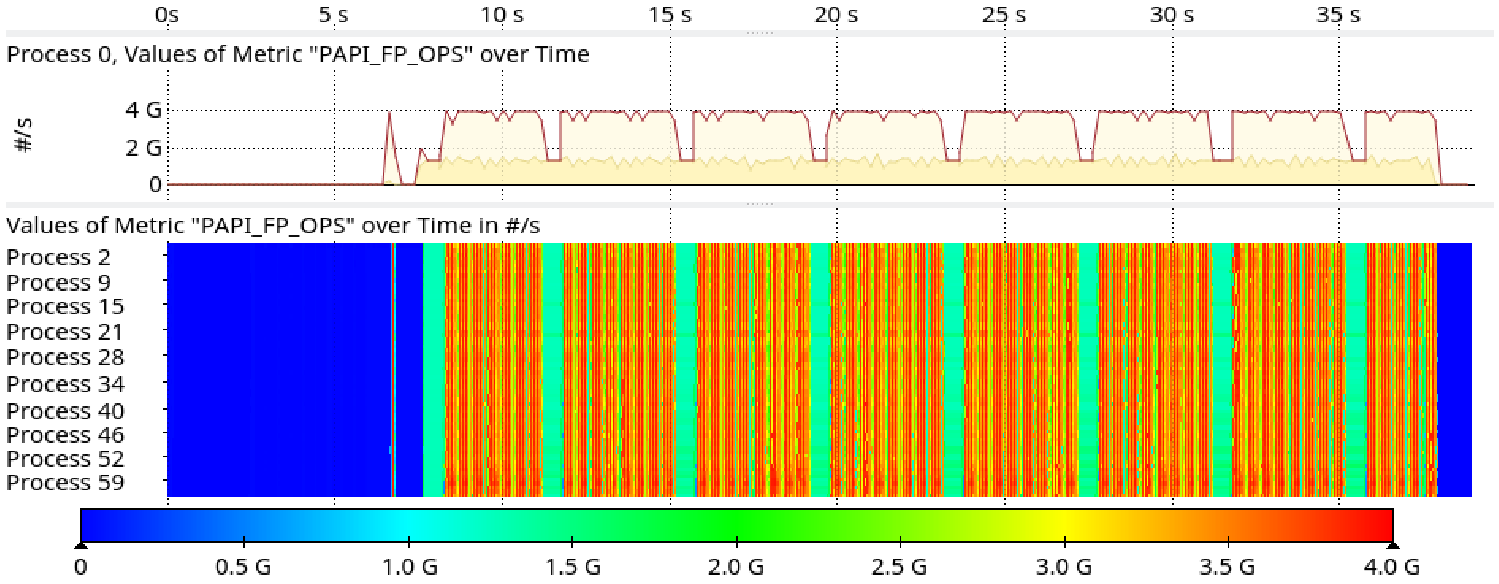
Analyze Runtime Imbalances

- Therefore, ignore synchronization time
  - *Synchronisation-oblivious segment time (SOS-time)*



Visualize Runtime Imbalances

- Implemented in Vampir [5]
- Present SOS-time as a per-process counter



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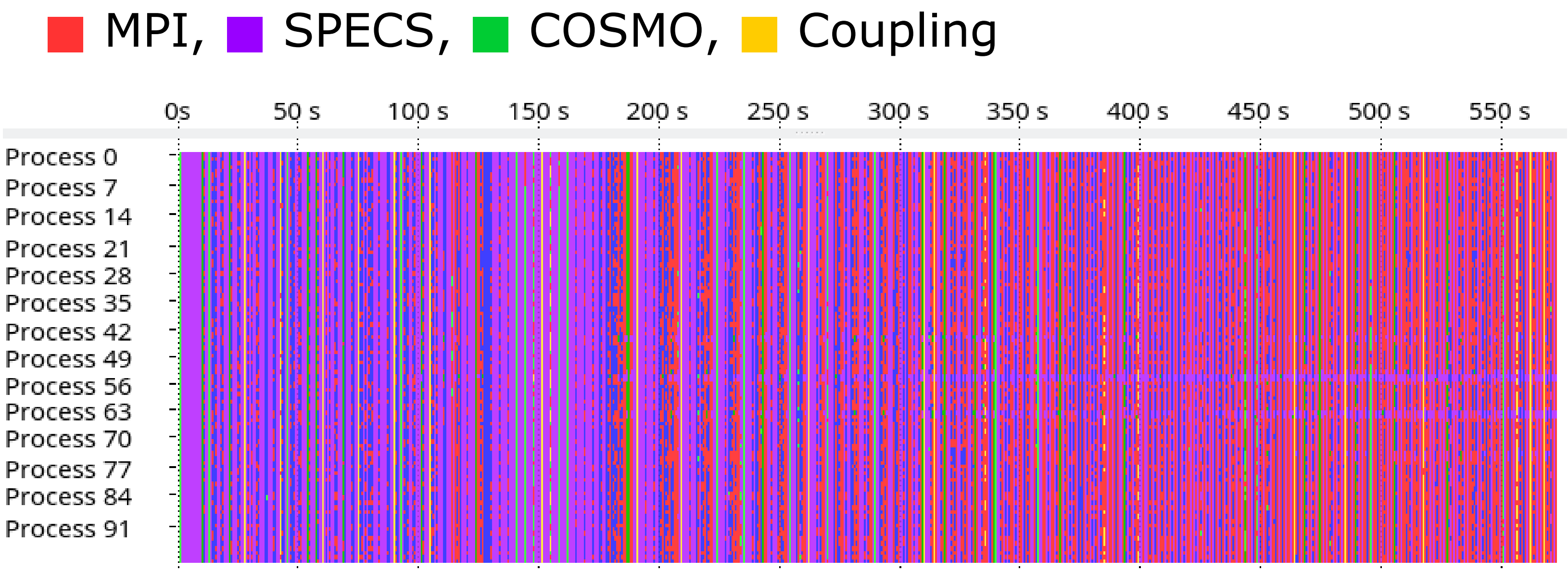
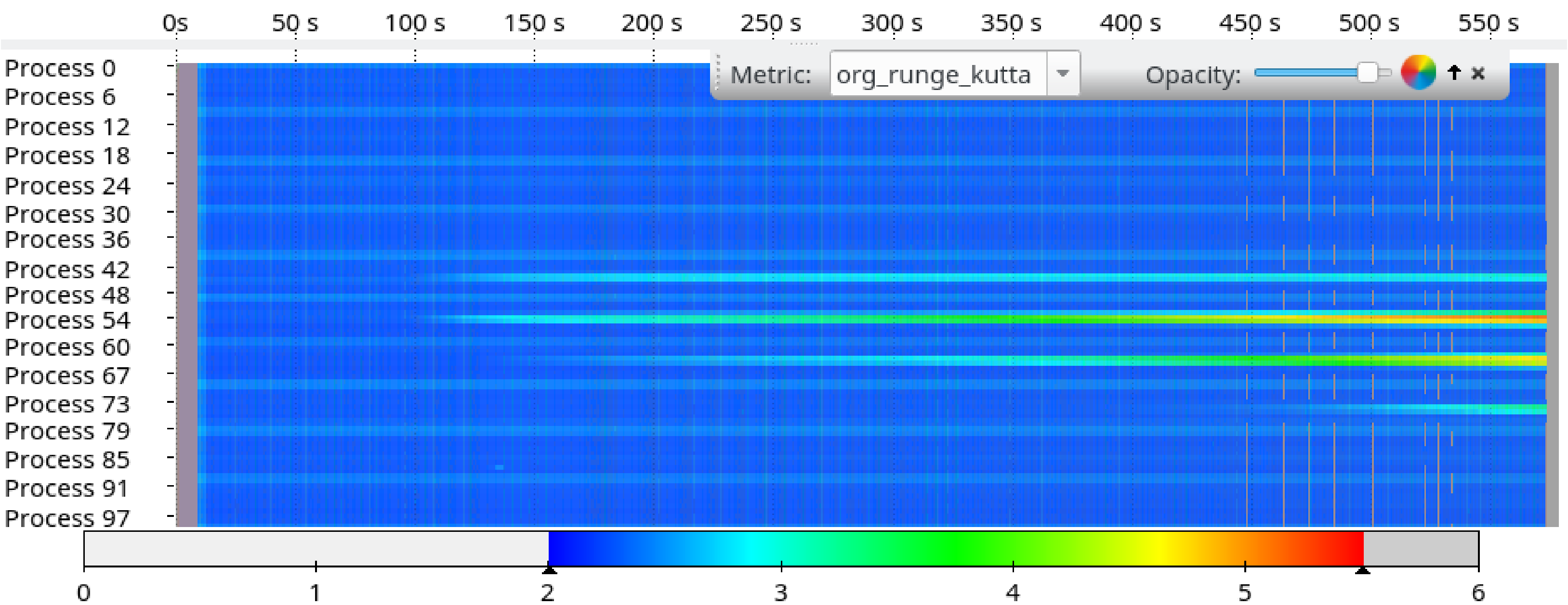
Load-Imbalance

- COSMO-SPECS [6]:
  - COSMO: Regional weather forecast model
  - SPECS: Cloud Micro-physics simulation

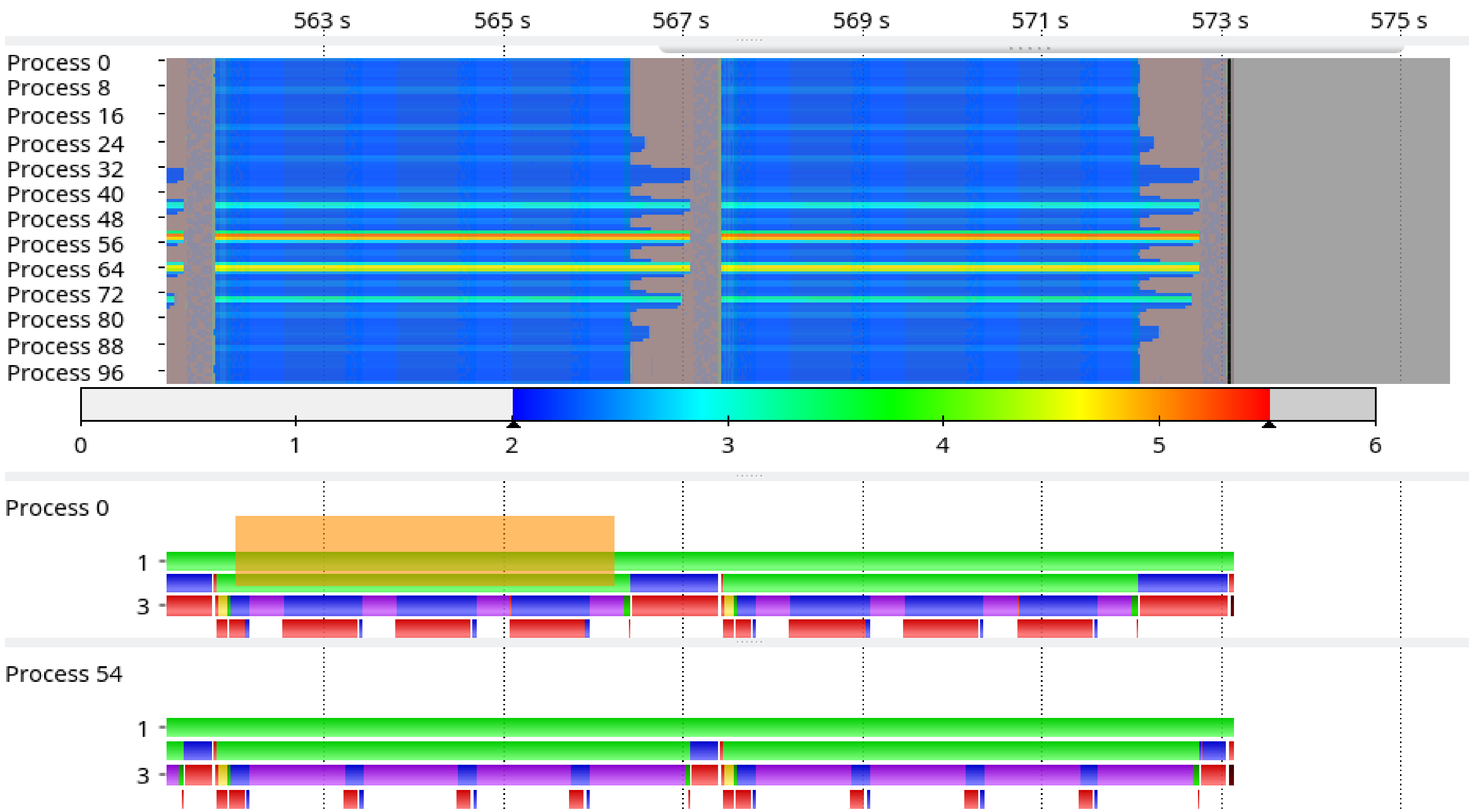


Load-Imbalance

- COSMO and SPECS use the same static domain decomposition
  - Cloud microphysics workload heavily depends on cloud shape



Load-Imbalance

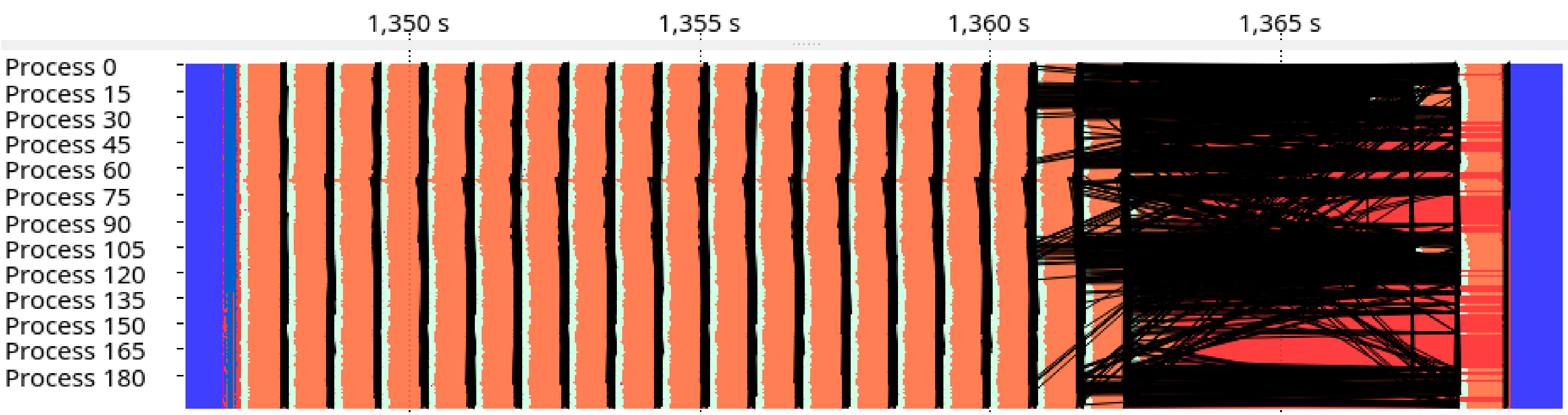


Process Interruption

- COSMO-SPECS+FD4 [7]: Load-balancing for COSMO-SPECS

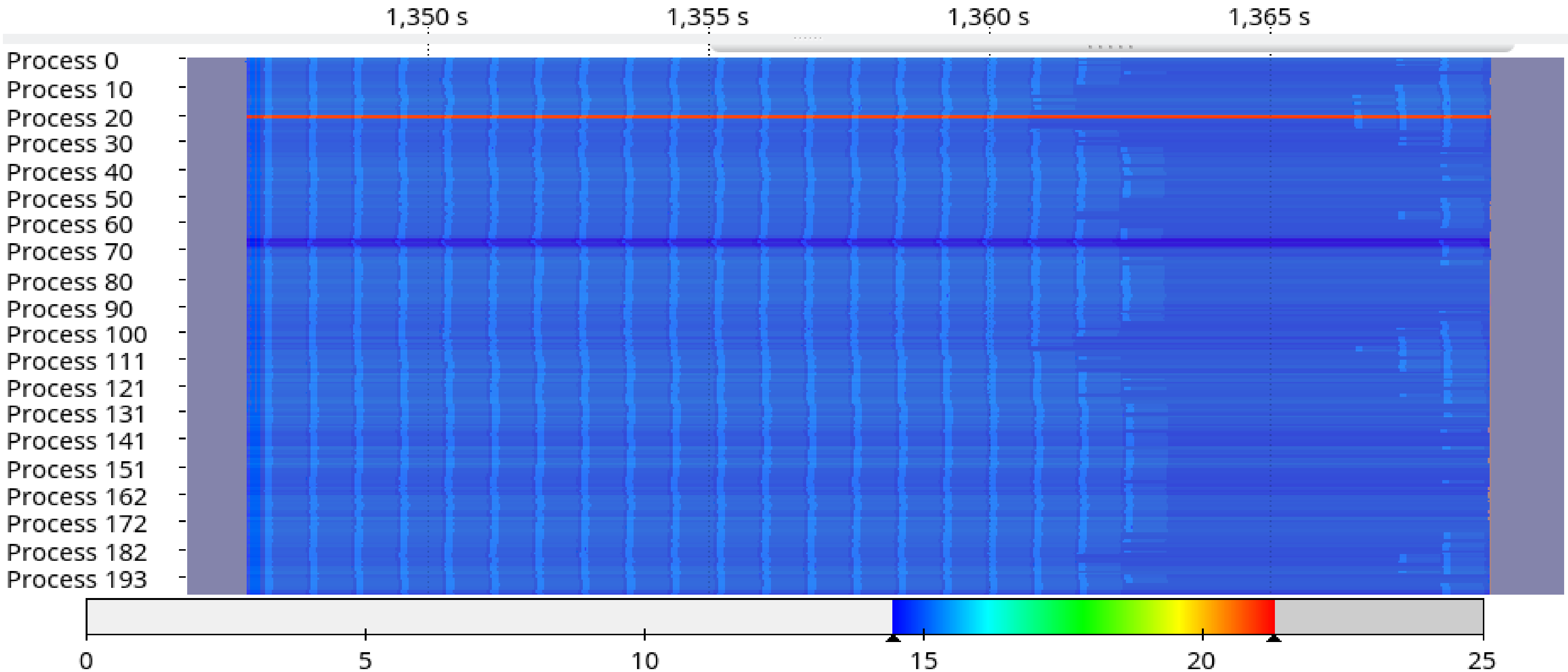
- First analysis detected that only few iterations are slow
- Second run only recorded slow iterations. Focus on one of them

■ MPI, ■ Dropped, ■■ SPECS, / messages



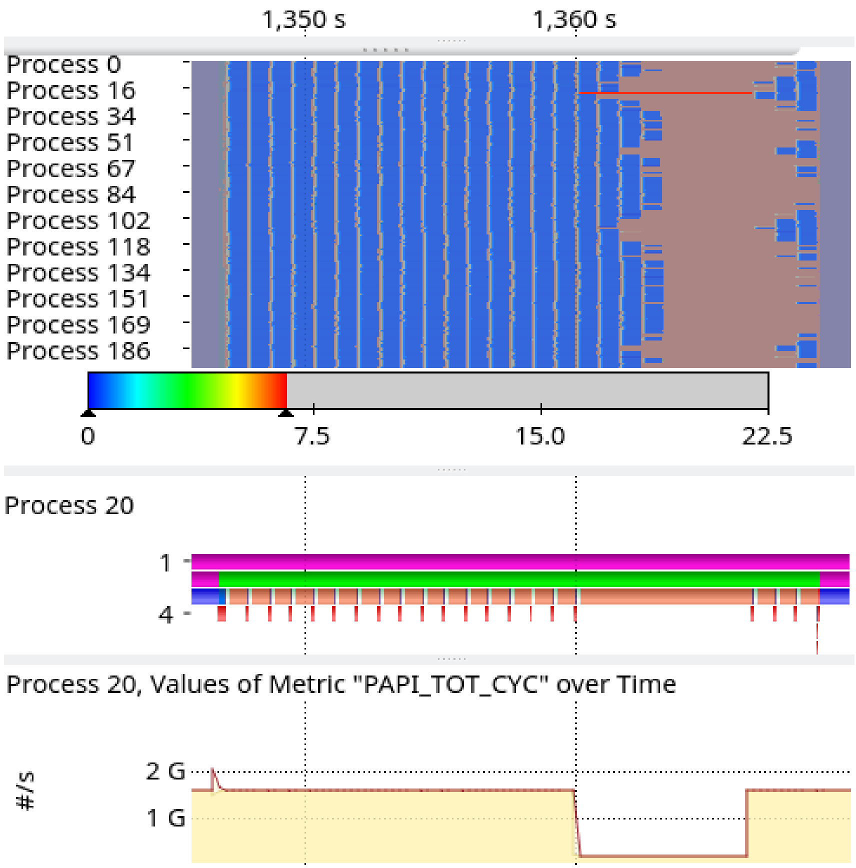
Process Interruption

- Process 20's time-dominant function has a larger SOS-time
- But where exactly is the time spent? → Refine by picking a different function for the metric



Process Interruption

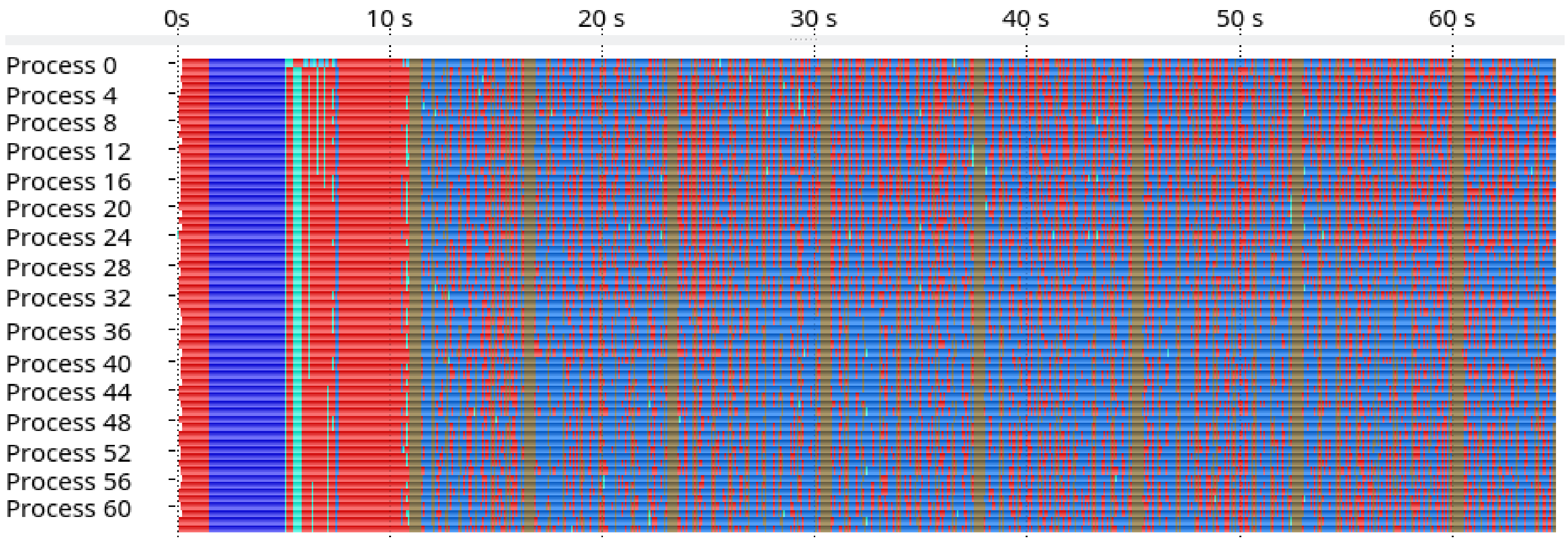
- One sub-iteration is very slow
- The total number of cycles per second during its runtime is ~150M/s vs 1500M/s in other iterations
  → Process is interrupted
- Operating system influence



Floating-Point Exception

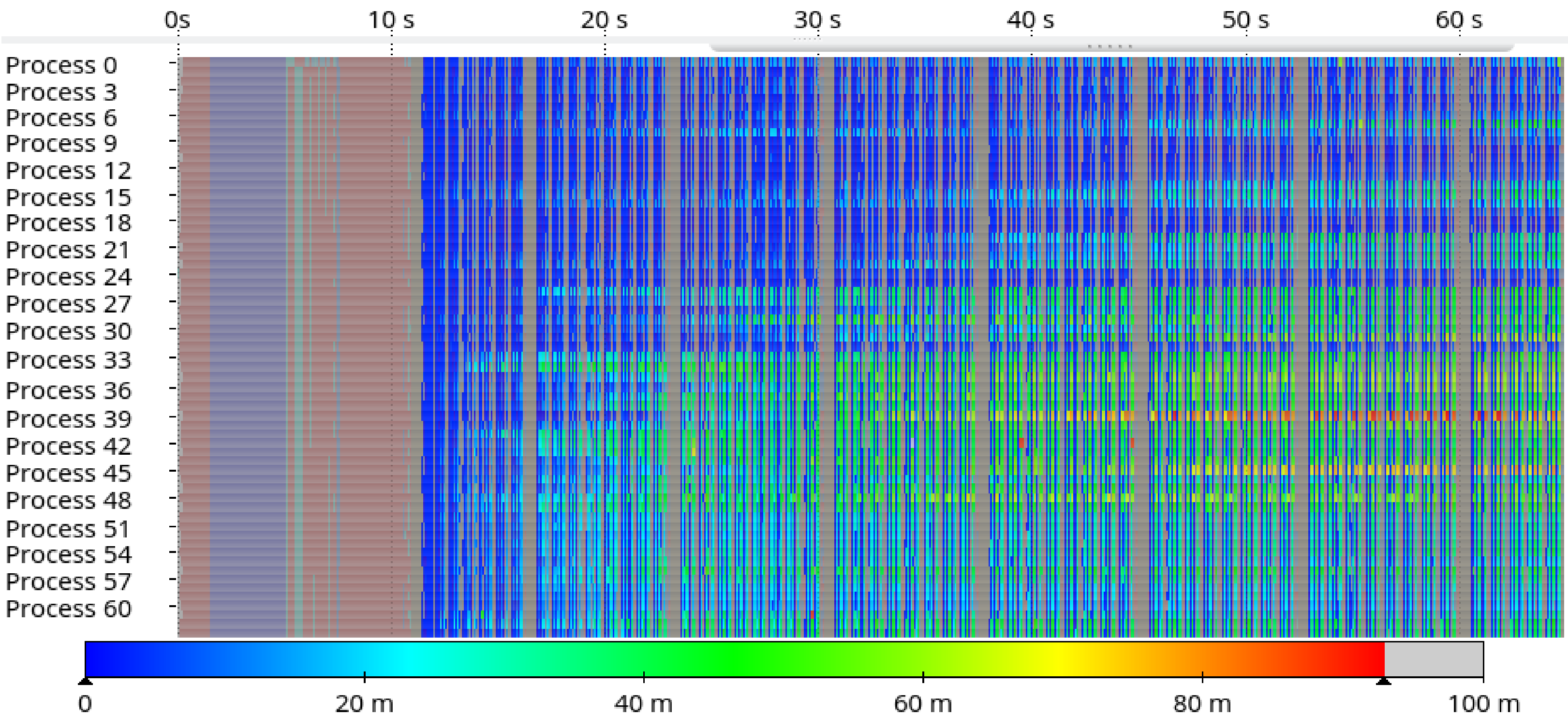
- WRF [8]:
  - Benchmark case: 12km CONUS

MPI, dynamical core, physical parameterization



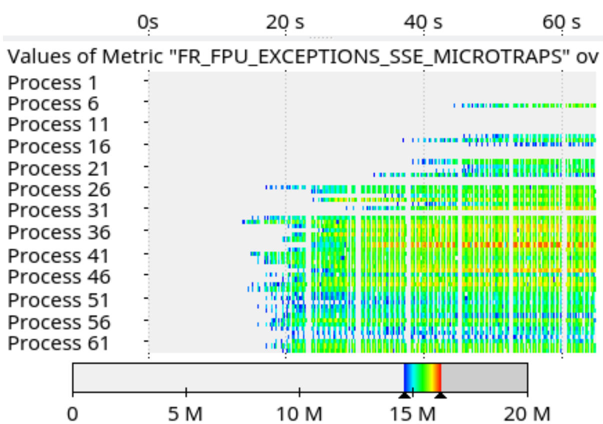
Floating-Point Exception

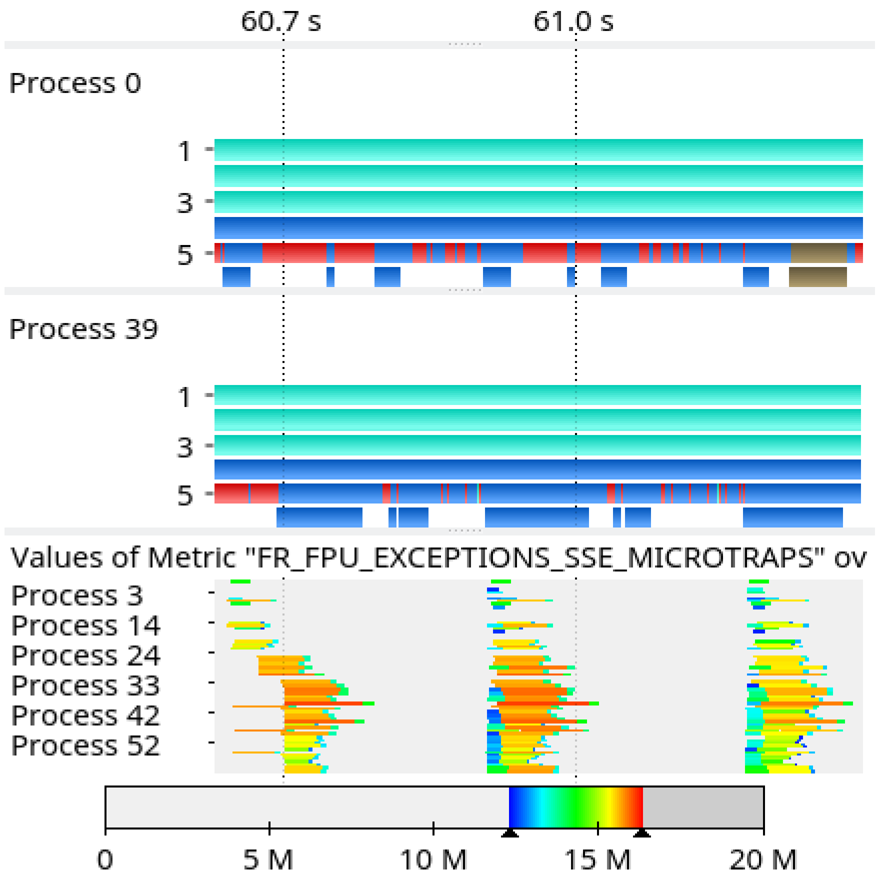
- Varying runtime of the time-dominant function across processes
- Process 39 stands out



Floating-Point Exception

- The function which takes longer is floating-point-intensive
- Number of floating-point exceptions is very high on slow processes



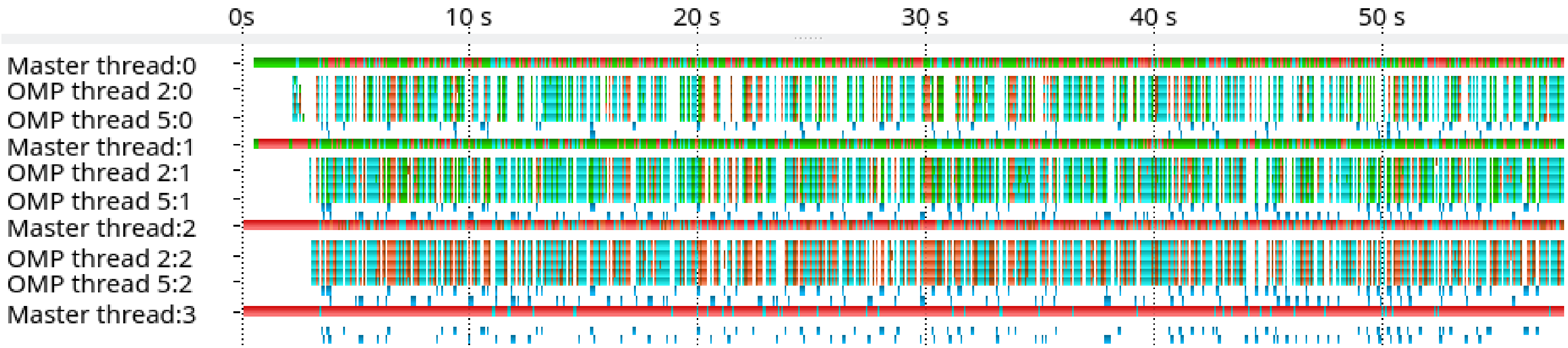


Conclusion

- Effective, light-weight approach that facilitates visual analysis of performance data, i.e. helps find runtime imbalances
  - First, identifies the recurring function with the largest impact on overall program runtime
  - Second, calculates the execution time for each invocation of this function, excluding synchronization time
  - Highlights performance variations by visualizing this synchronization-oblivious segment time
- We demonstrated its effectiveness with three real-world use cases

Future Work

- Use structural clustering [9] to only compare processes doing similar work (e.g. categorize processing elements into process, thread, CUDA thread, ...)



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