Optimizing application performance through optimizing compilation

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Objective

Explore how compilers optimizes programs using several optimizations levels : `-O0` , `-O1` , `-O2` , `-O3` , `-Os` .

2 parts to the project

1. Compiling 2 programs in `C` /`C++` with each optimization level and compiler to compare performances
2. Checking which optimization is enabled for each optimization level and compiler

Configuration

Computer in a lighweight configuration, avoid OS's optimizations and bloat from other programs or graphical interface.

OS and compilers

OS : Fedora Linux Workstation v40

gcc : version 14.2.1

icx : version 2024.2.1

clang : version 18.1.8

ccomp : version 3.14

Programs

There are 2 programs to compile : Matrix Multiplication (`C`) and Dijkstra's algorithm (`C++`). For each compiler and optimization level.

Object Size

The matrix size is set to two times the size of the largest cache. The graph size is really huge to have a significate execution time.

Mesurement

Function `gettimeofday()` placed before and after the main computation, mesuring initialisation time is not the goal.

Finally

Run each program 12 times to visualize the data with R

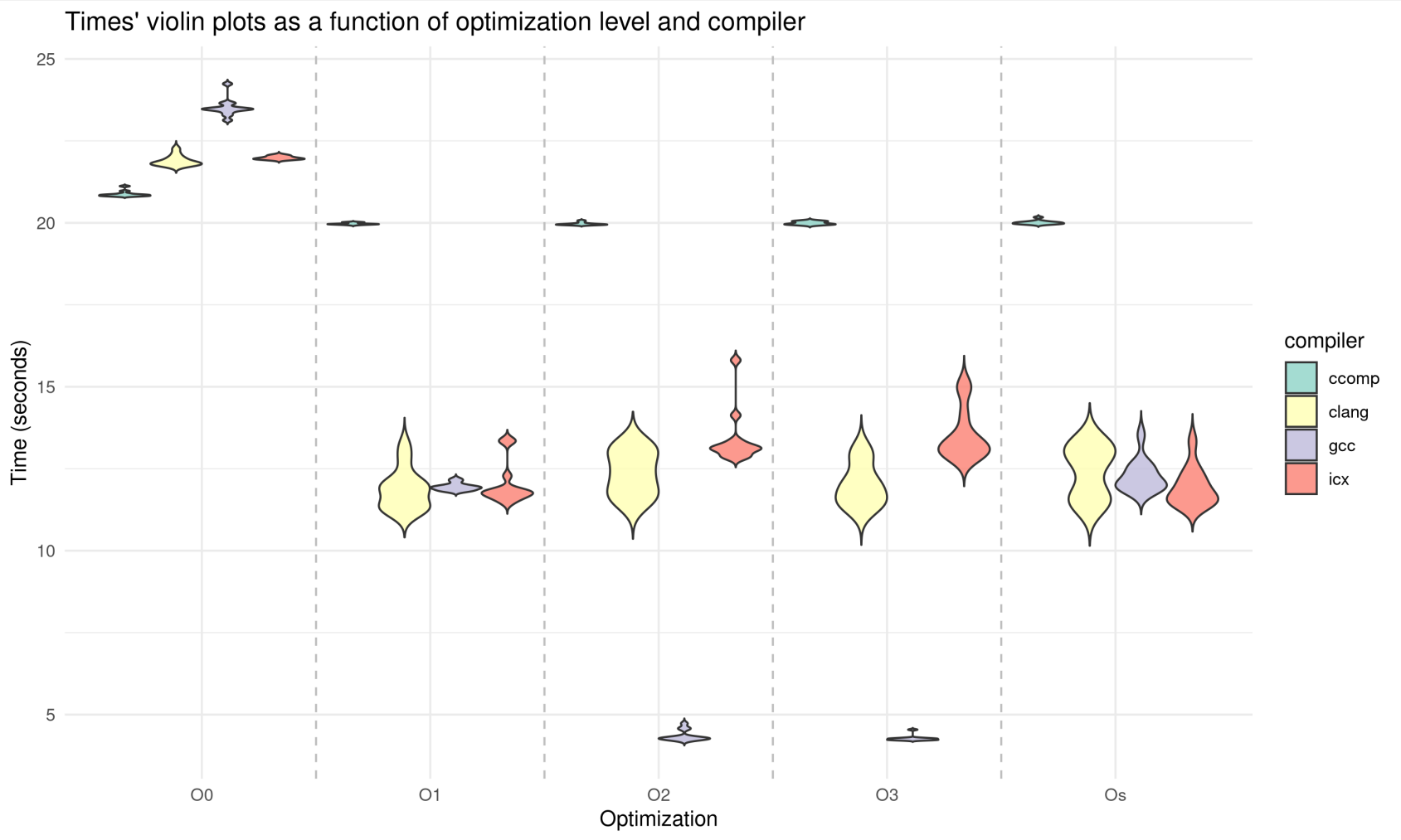

Figure – Evolution of the execution time of the program mat_mult.c as a function of compiler and optimization level.

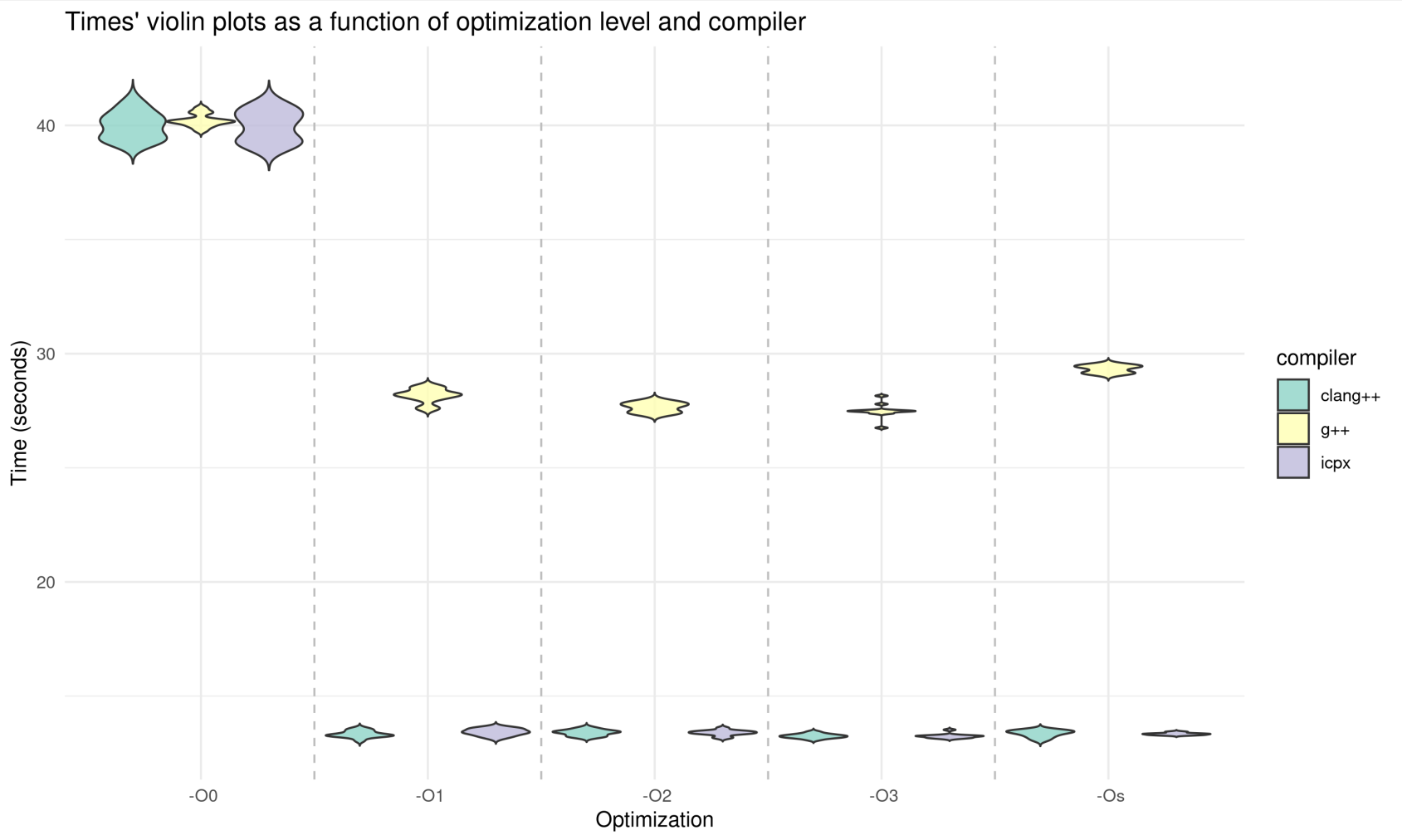

Figure – Evolution of the execution time of the program dijkstra.c as a function of compiler and optimization level.

	gcc	clang	icx
total time taken	136.37s	146.98s	155.65s
dijkstra usage	$\approx 19\%$	$\approx 9\%$	$\approx 11\%$
init/free usage	$\approx 81\%$	$\approx 91\%$	$\approx 89\%$

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C++ type inference

```
for (auto edge : temp_neighbors)
```

gcc

```
gcc --help=optimizers -Q -On
```

clang

```
clang -On -emit-llvm -S program.c -o program.ll
opt -On -debug-pass-manager program.ll -o program.ll
```

icx and ccomp

Everything is inside their documentation.

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Elimination of common subexpressions

Reuse previously computed values.

Dead argument elimination

Removes unused function arguments.

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Loop jamming/fusion

Combine two adjacent loops into a single loop.

Does not activate much, but it has its optimizations !

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ccomp

ccomp focuses on formally verified code translation so optimizations and performance is not a question.

gcc

gcc is the most efficient in general-purpose tasks and nested loops in C .

clang

clang was the most performant on C++ programs using specific features like type inferences.

icx

icx not being the most performant on this configuration could mean that the compiler is made for other types of workloads.

Each compiler has its own purpose, so it's important to choose the right compiler for a specific task.

What next ?

Further exploration on *energy consumption* optimization, in line with the model of Apple, a balance between *power* and *efficiency*.