Code performance analysis and improovement by optimasing compilation : Case study

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Outline

The program

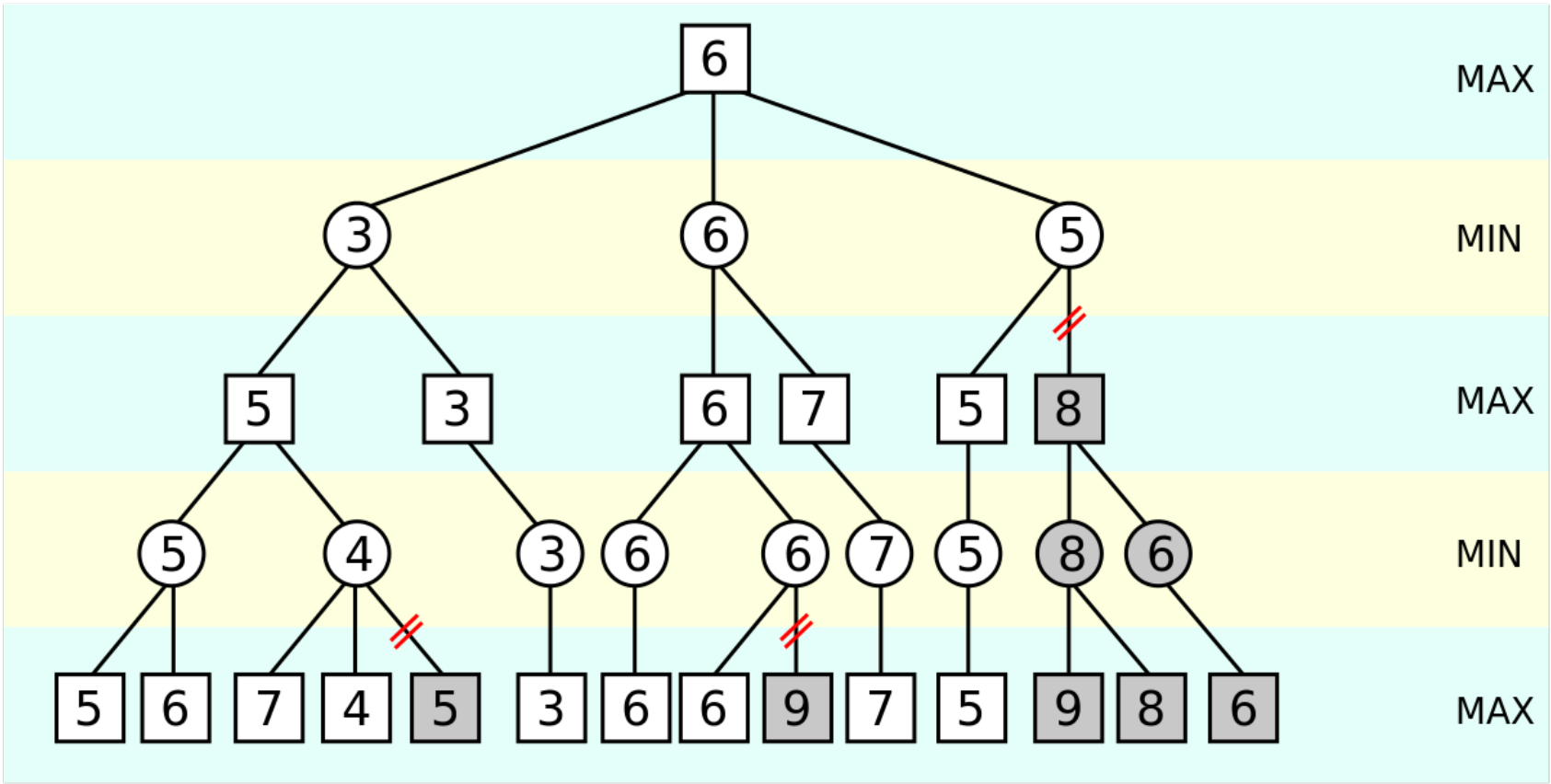
MinMax for the Awale game

- AI for Awale's game with 6 row and 4 seed per row.
- Writen in C++ by Pr Régin.

Figure: The Awale's game.

The program

MinMax with Alpha Beta prunning

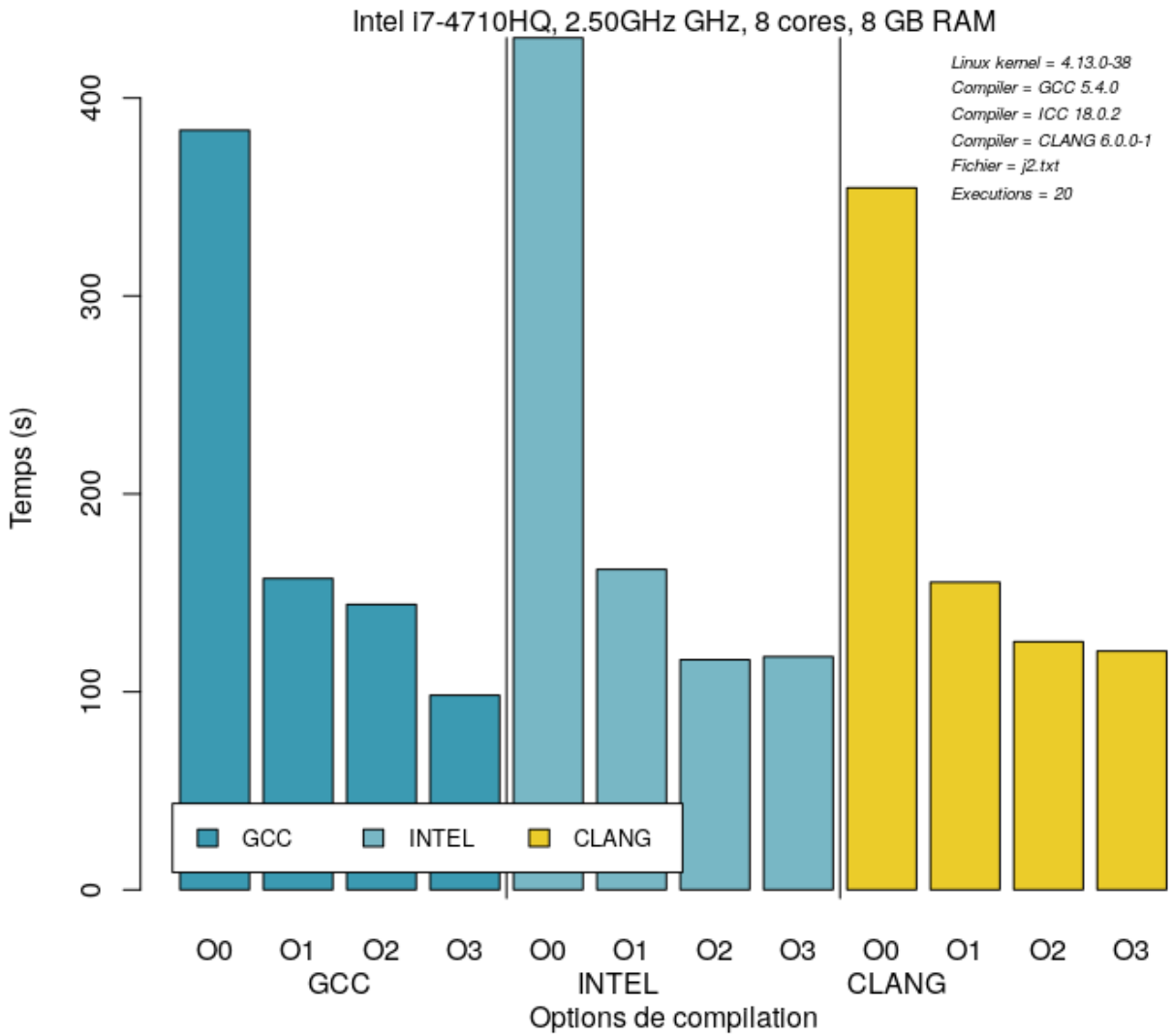


Experimental approach

Hardware and software environment

- *Processeur Scaling* desactivated, Intel core i7 8 core 2,5GHz processor, 8Go DDR3, 256Go of SSD.
- Minimalist CLI environement, Arch Linux based on Linux 4.14.13-1.
- Three compiler analysed : GCC, ICC and CLang (all up to date).
- Input file generated by playing the program against itself, deterministic program.
- The executions are repeated 20 times for each tested configuration.

Analysis and optimization of sequential performances



Code performance profiling

GProf

```
 %   cumulative          total
time   seconds   calls   s/call  name
48.83    167.72 5172852992  0.00  jouer_coup(Next*, Pos*, Pos*, int, int)
18.25    230.39 3262157329  0.00  copier(Pos*, Pos*)
17.22    289.56 3262157262  0.00  est_affame(Pos*, int)
 8.79    319.75 1457826958  0.00  calculer_coup(Next*, Pos*, int, int, int, int, bool)
 5.31    337.98 3252245939  0.00  valeur_minimaxAB(Next*, Pos*, int, int, int, int, bool)
 0.87    340.99 1775297034  0.00  evaluer(Pos*)
 0.52    342.77     67      0.03  test_fin(Pos*)
 0.09    343.65     33     10.34  decisionAB(Next*, Pos*, int, bool)
```

Figure: Code Profiling with GProf.

Elapsed Time: 118.666s

CPU Time:	**117.755s**
Instructions Retired:	588,377,500,000
CPI Rate:	0.499
CPU Frequency Ratio:	1.000
Total Thread Count:	1
Paused Time:	0s

Top Hotspots

This section lists the most active functions in your a

Function	Module	CPU Time
jouer_coup	advisor.out	70.132s
calculer_coup	advisor.out	15.441s
copier	advisor.out	14.165s
est_affame	advisor.out	7.176s
valeur_minimaxAB	advisor.out	5.755s
[Others]		5.087s

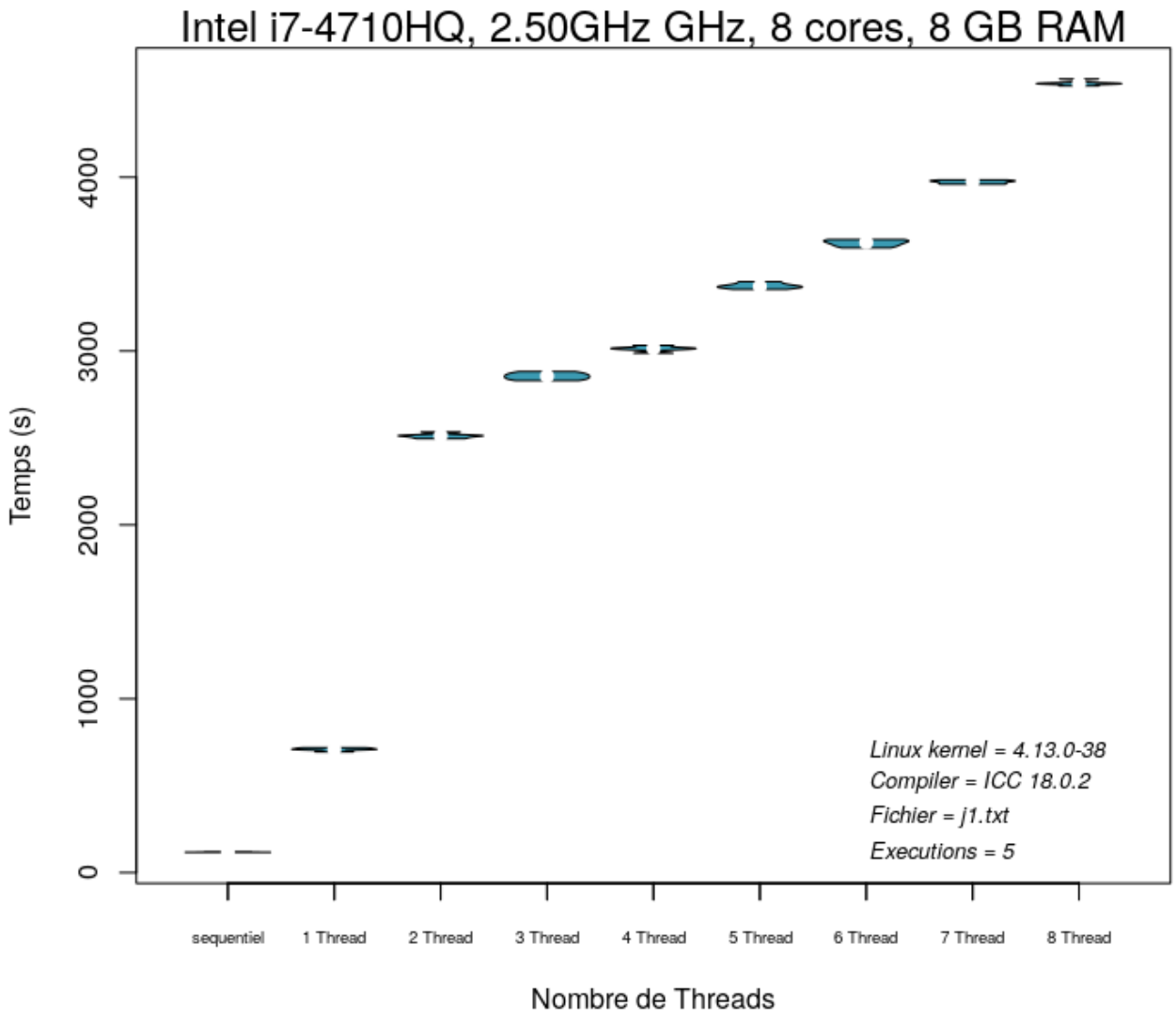
Figure: vTune processor usage analysis.

Elapsed Time: 120.174s

CPU Time:	118.454s
Memory Bound:	**2.7%**
L1 Bound:	6.6%
DRAM Bound:	
DRAM Bandwidth Bound:	0.0%
LLC Miss:	0.1%
Loads:	157,360,120,662
Stores:	100,867,825,944
LLC Miss Count:	900,054
Average Latency (cycles):	8
Total Thread Count:	1
Paused Time:	0s

Figure: vTune memory usage analysis.

Naïve approach to adding parallelism



False Sharing

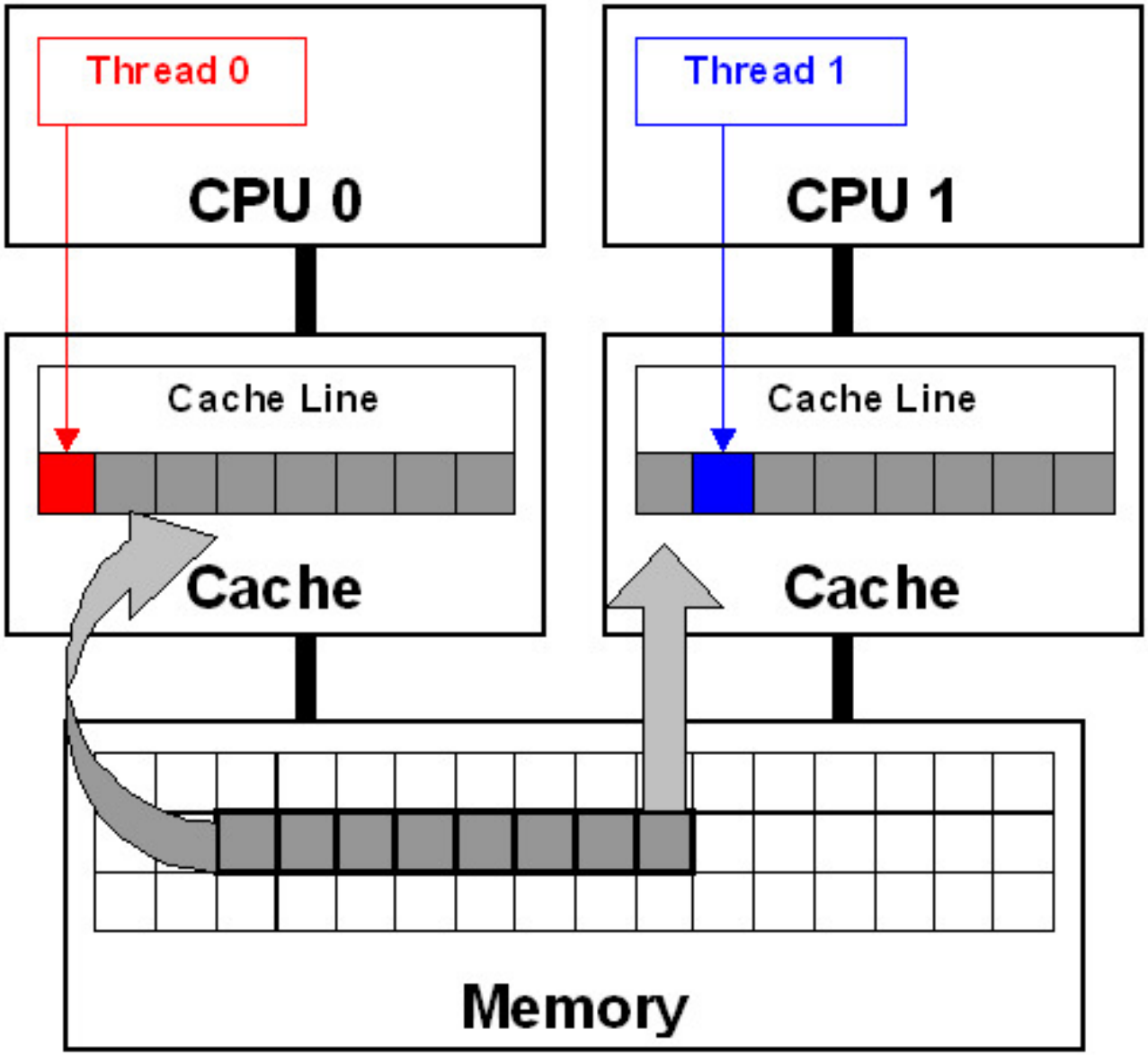
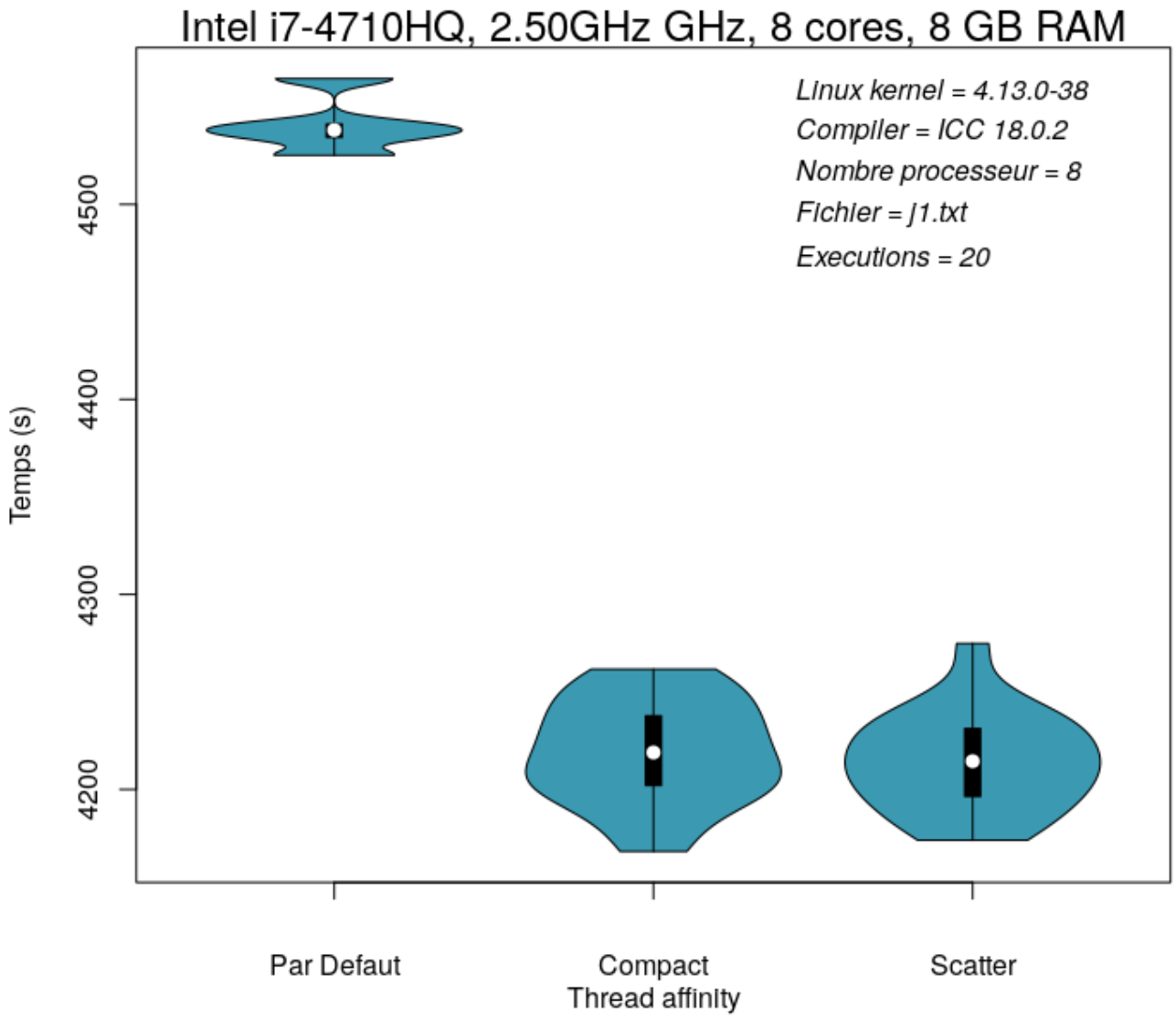


Figure: False Sharing.

Source : Intel's Documentation.

Thread Affinity

Figure: Analyzing the impact of thread placement with the Intel compiler, **-O3** with 8 CPUs.



Intel Advisor

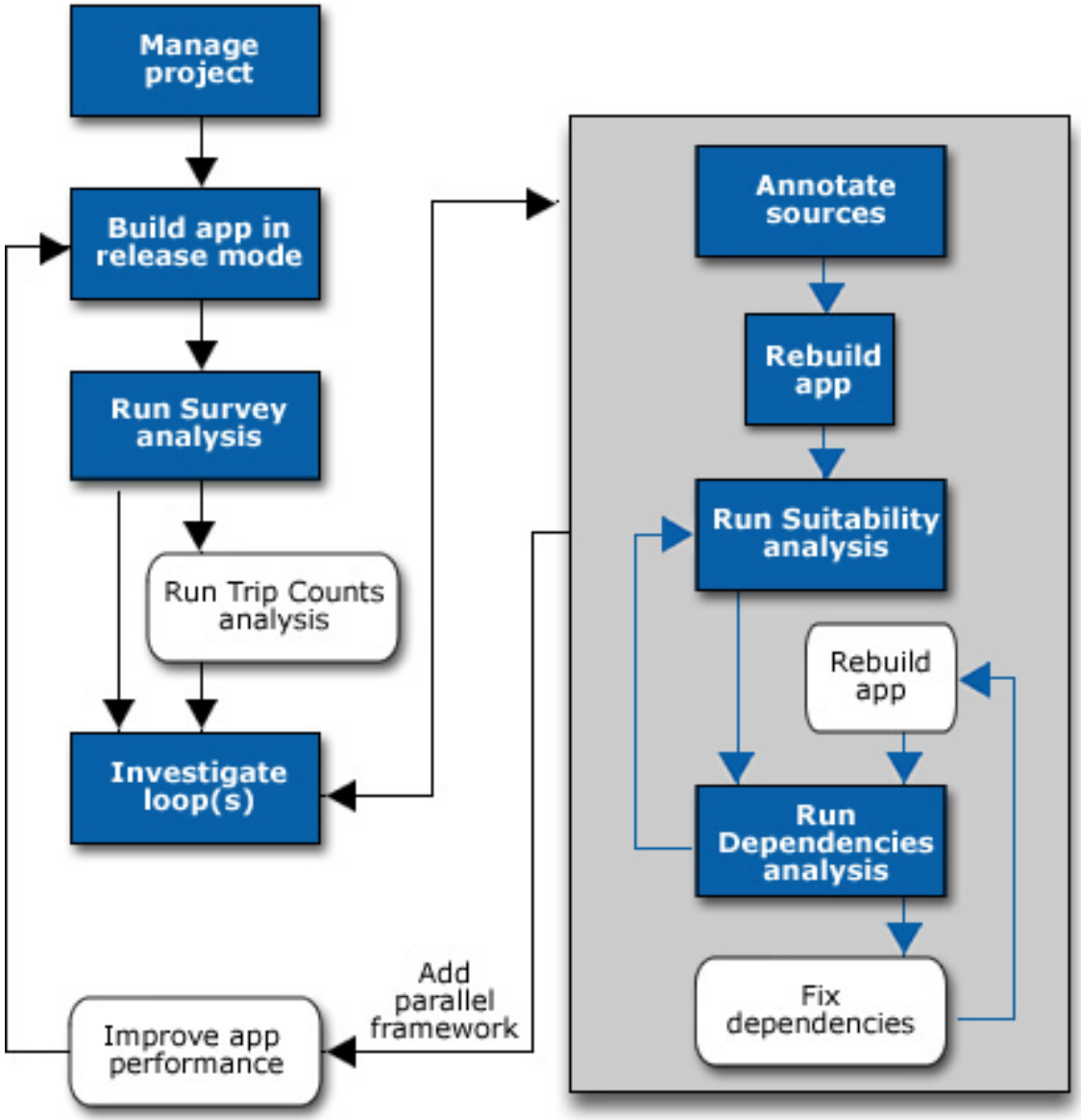


Figure: Iterative method to add parallelism (proposed by Intel).

Source : Intel's Documentation.

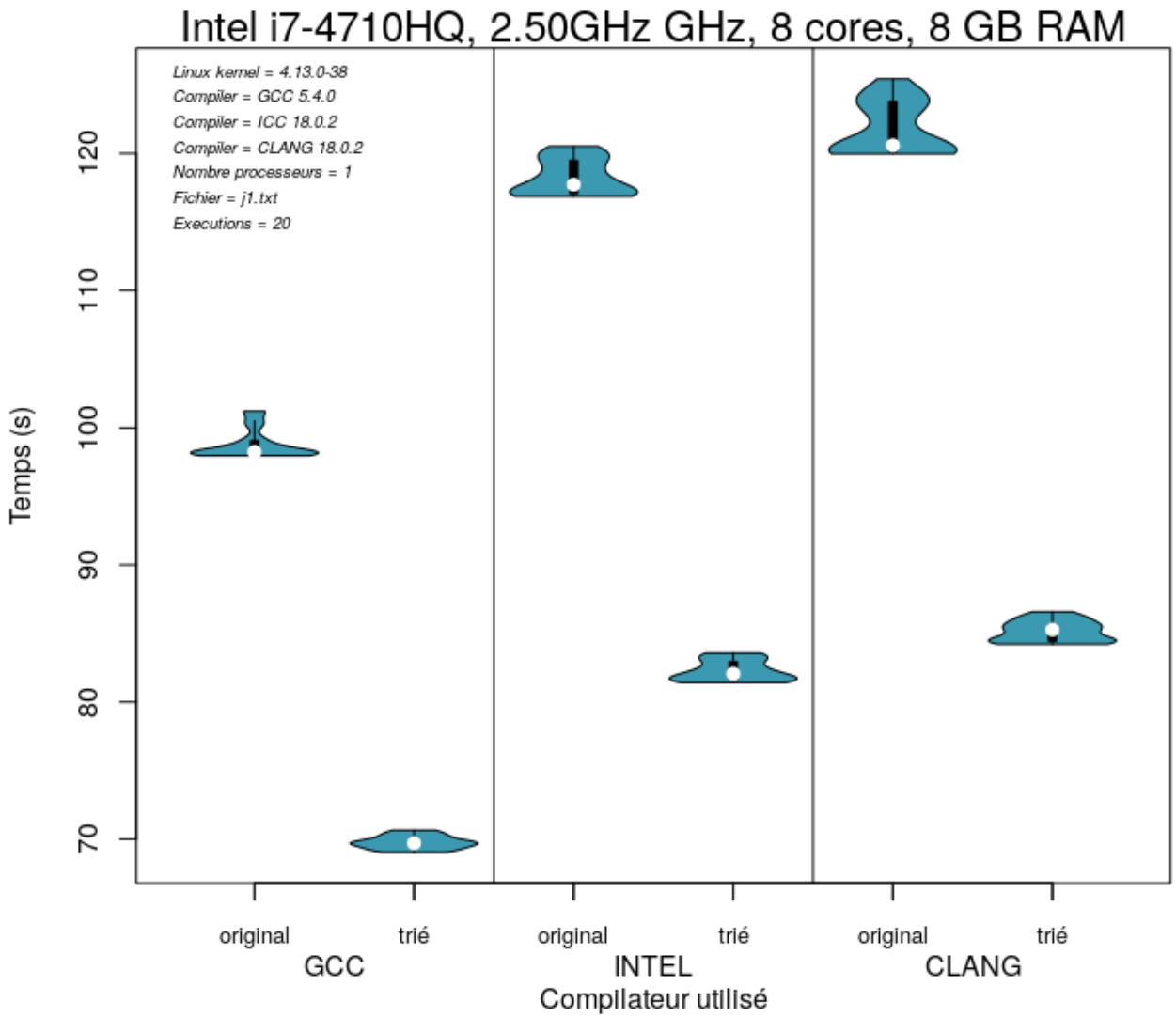
Difficulties of code optimization

- Very sequential algorithm.
- Low number of iterations ($n = 6$).
- Lot of usage of pointers that could blind the compiler's optimisation passes.

Simple algorithmic modification

- Sort the "moves" to evaluate.
- Transposition table.

Sort the "moves"



Transposition table

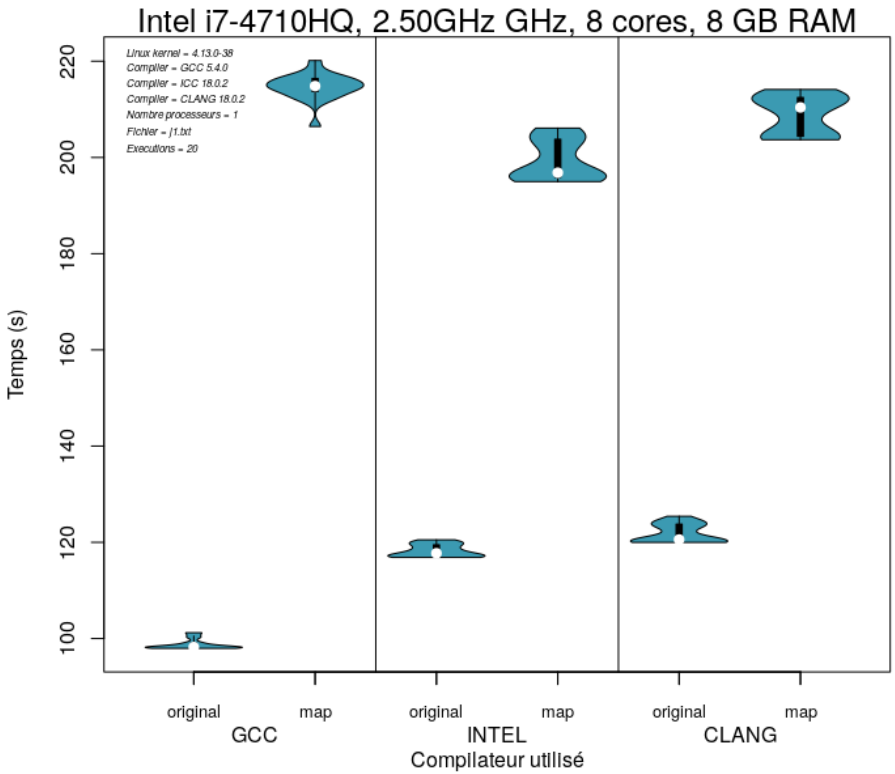


Figure: Binary search tree.

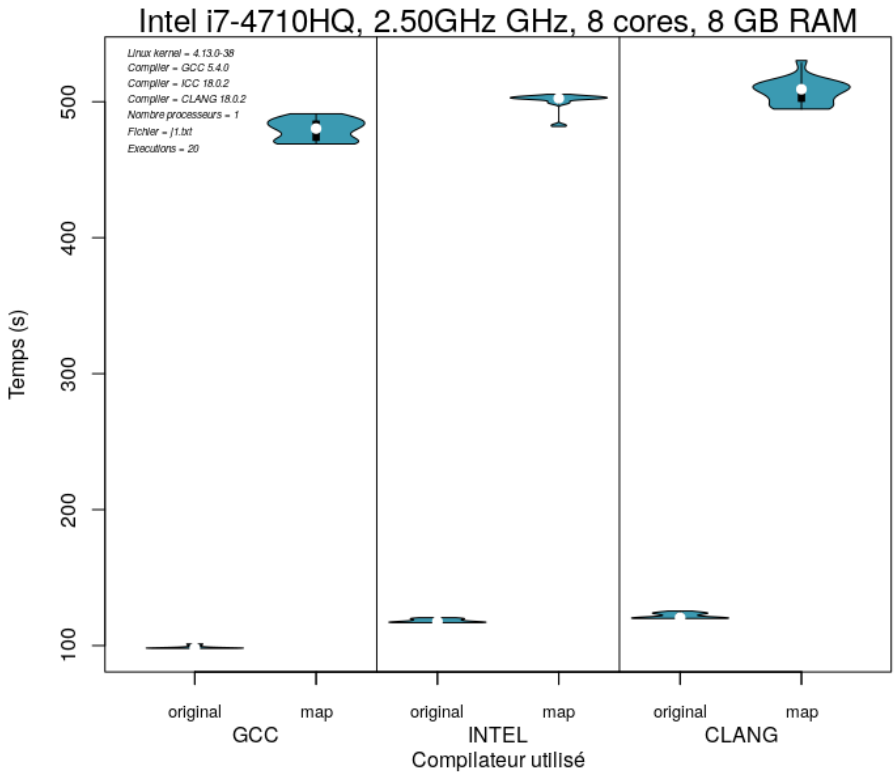


Figure: Hash table.

Conclusion

- GCC beats ICC for a sequential code on Intel's architecture.
- Parallelization with OpenMP can severely degrade performance.
- False Sharing phenomena.
- Algorithmic changes needed to improve performance.

Perspectives

- Array padding to reduce the false sharing problem.
- Speculative execution.