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Portability of Vectorization-aware Performance Tuning Expertise across System Generations

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Background

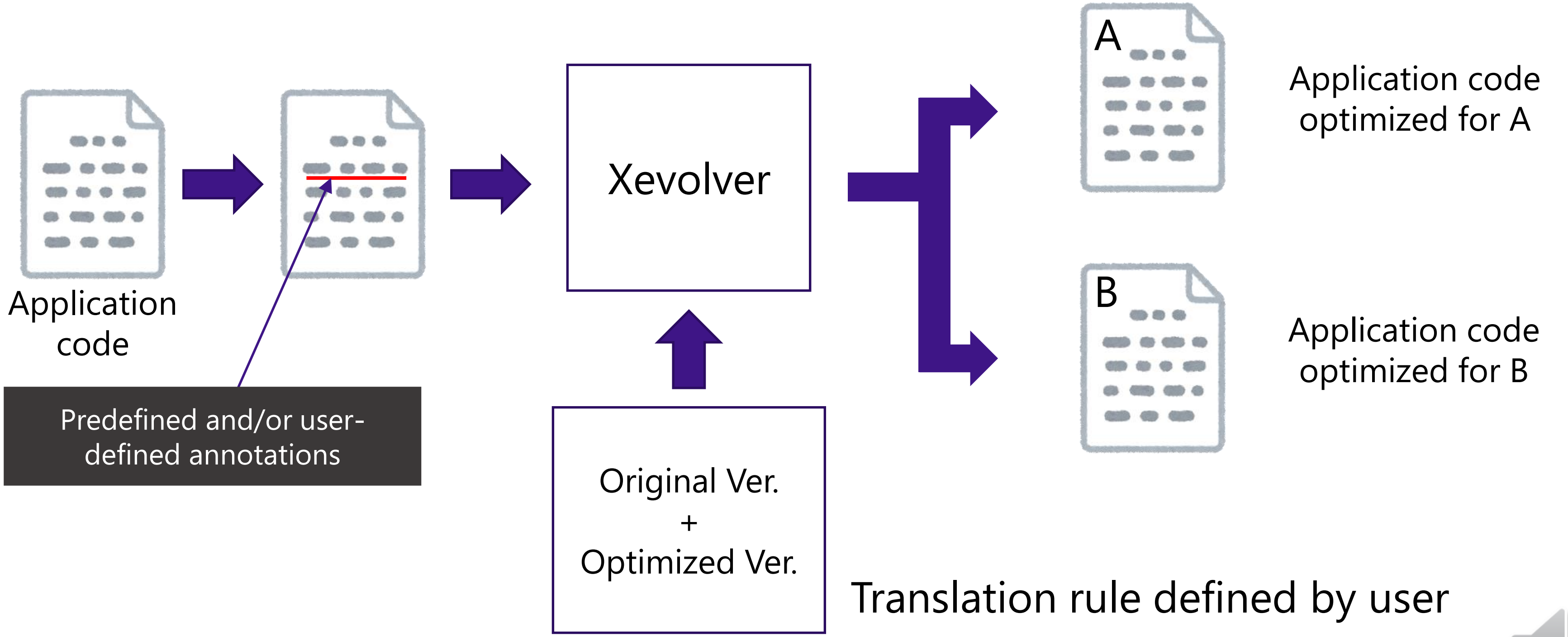
- Software automatic tuning (Auto-tuning)
  - To reduce the effort of code optimization, **auto-tuning** adjusts various parameters (**performance knobs**) that affect performance.
    ex.) Block size, Loop length, etc.
- Portability of performance knobs
  - Is a performance knob for old systems effective also for new systems?
    - Or, new performance knobs are needed?
      →The application code would be overcomplicated if it has too many performance knobs.

This Work

- Objectives
  - To discuss the portability of effective performance tuning techniques across system generations
  - To explore a way of cataloging portable techniques in a future-proof way
- Contributions
  - Empirically showing how differently a performance tuning technique affects the performance of each system generation
  - Discussing how a performance tuning technique should be expressed and applied to an application.

Related Work

- Xevolver code transformation framework [1]
  - System-neutral **Fortran** codes are translated into system-specific codes according to user-defined code translation rules



[1] K. Komatsu, A. Gomi, R. Egawa, D. Takahashi, R. Suda, and H. Takizawa, "Xevolver: A code transformation framework for separation of system-awareness from application codes," Concurrency and Computation: Practice and Experience, vol. 32, no. 7, pp. 1–20, 2019.

Related Work

- HPC refactoring catalog [2]
  - 31 cases of performance tuning expertise
    - Target systems : NEC SX-9 and SX-ACE
    - Code examples : mostly in Fortran

- Is it still useful for new systems?
  - **NEC SX-Aurora TSUBASA (SX-AT) [3]**
    - The latest generation of SX-series systems
    - Totally different system architecture and software stack
      - C/C++ as well as Fortran used

[2] R. Egawa, K. Komatsu, and H. Takizawa, "Designing an open database of system-aware code optimizations," in The Fifth International Symposium on Computing and Networking (CANDAR), 2017, pp. 369–374.
[3] Y. Yamada and S. Momose, "Vector engine processor of NEC's brand-new supercomputer SX-Aurora TSUBASA," in In Proceedings of Symposium on High Performance Chips (Hot Chips), vol. 30, 2018, pp. 19–21.

Translating Fortran to C

- Why C ?
  - C language is getting more popular in HPC
  - We are now developing Xevolver[1] for C
    - A code translation framework for maintaining performance portability

- 28 out of 31 examples are translated
  - 3 code examples cannot be translated because these examples contain:
    - Fortran's built-in functions that do not exist in C
    - library functions that do not have C interface

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[1] K. Komatsu, A. Gomi, R. Egawa, D. Takahashi, R. Suda, and H. Takizawa, "Xevolver: A code transformation framework for separation of system-awareness from application codes," Concurrency and Computation: Practice and Experience, vol. 32, no. 7, pp. 1–20, 2019.

Xevolver for C : translation rule

- User-defined code translation rule
  - xev_expr n: any variable, expression
  - xev_stmt stmt: any statement
  - xev_stmt_src,dst: indicates the code before and after the translation
  - xev_expr_replace: translate a specific expression to a specified form

```c
#include "xev_defs.h"

int i,j;
xev_expr n;
xev_stmt* stmt;


int main()
{
    xev_stmt_src("label1");
    {
        for(i=0;i<10;i++){
            for(j=0;j<10;j++){
                stmt;
            }
        }
    }
    xev_stmt_dst("label1");
    {
        for(j=0;j<10;j++){
            for(i=0;i<10;i++){
                stmt;
            }
        }
    }

    xev_expr_replace(pow(n,2),(n)*(n));
}
```

before

after

before after

Xevolver for C : before and after translation

- Applying the translate rule from the previous slide

```c
int main()
{
    int x,a,b,c,i,j;

    for(i=0;i<10;i++)
    {
        for(j=0;j<10;j++)
        {
            c = a * i + b * j;
        }
    }

    x = pow(c,2);

}
```

before

```c
int main()
{
    int x,a,b,c,i,j;

    for(j=0;j<10;j++)
    {
        for(i=0;i<10;i++)
        {
            c = a * i + b * j;
        }
    }

    x = c * c;

}
```

after

Evaluation setup

- 28 Examples of HPC refactoring catalog written in C
- System specifications
  - SX series have vector processor VE and x86 processor VH to run Linux OS
- Compiler
  - ncc -3.2.0(-O2,-O4)
  - ncc -2.5.1(-O2,-O4)
  - gcc-4.8.5
  - NEC LLVM-IR Vectorizer
- Metric

$$R = \frac{T_b}{T_a}$$

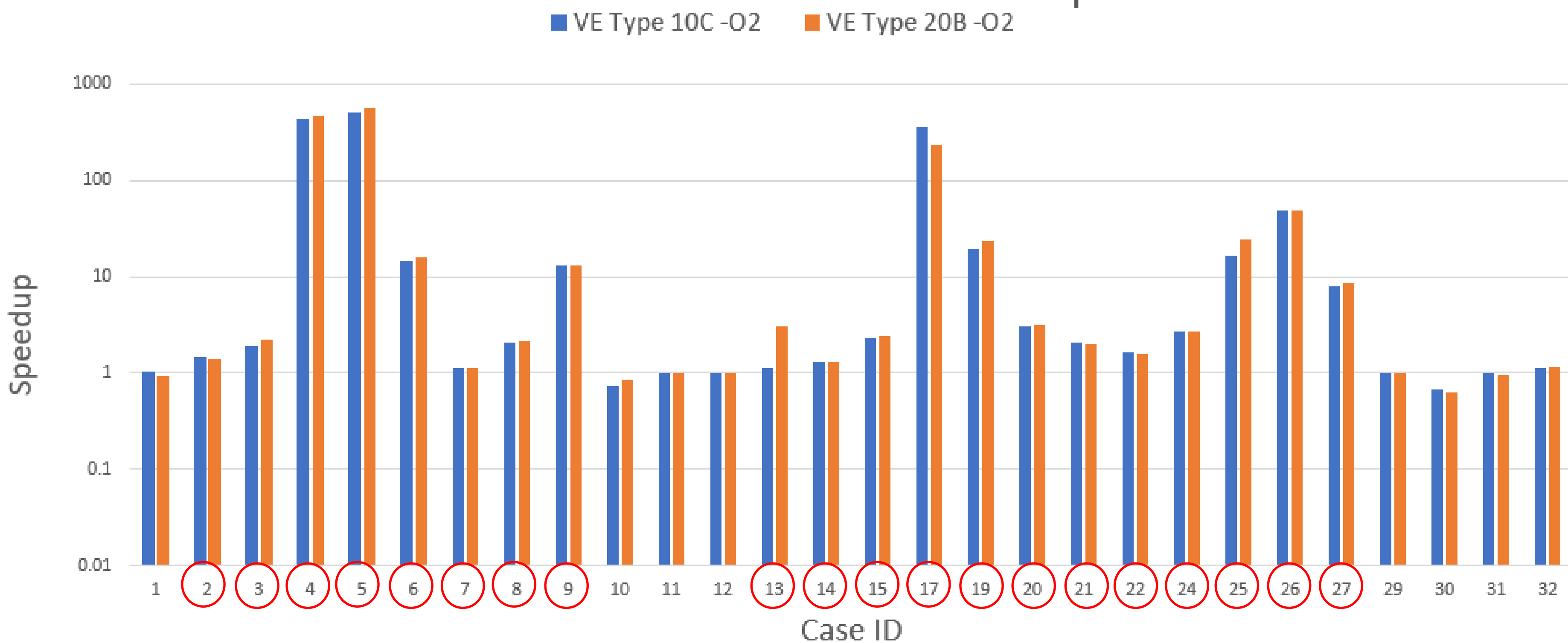
T_b: the execution time before the transformation

T_a: the execution time after the transformation

VE 1	Model	Type 20B
	Core Count	8
	Peak Performance [TFLOPS]	2.45
	Memory Bandwidth [TB/s]	1.535
	Memory Capacity [GB]	48
	Compiler	ncc-3.2.0
VE 2	Model	Type 10C
	Core Count	8
	Peak Performance [TFLOPS]	2.15
	Memory Bandwidth [TB/s]	0.750
	Memory Capacity [GB]	24
	Compiler	ncc-2.5.1
		clang-3.4.2
VH	Model	Intel Xeon Gold 6126
	Core Count	12
	Memory Capacity [GB]	96
	Operating System	CentOS 7.9.2009
	Compiler	gcc-4.8.5

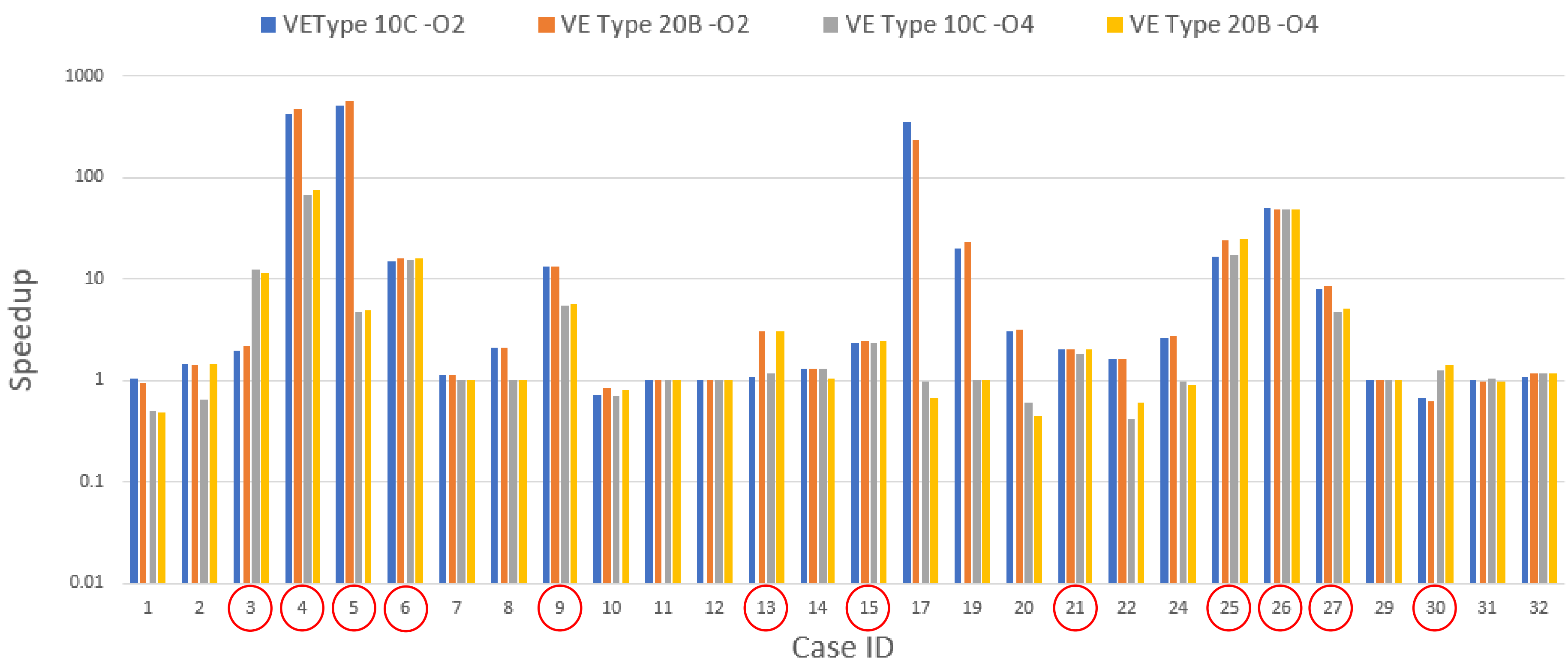
Evaluation : between different systems

- Performance improves in
  - ncc -O2: 20 out of 28 techniques
- There is little difference between them in terms of the effects of optimization techniques



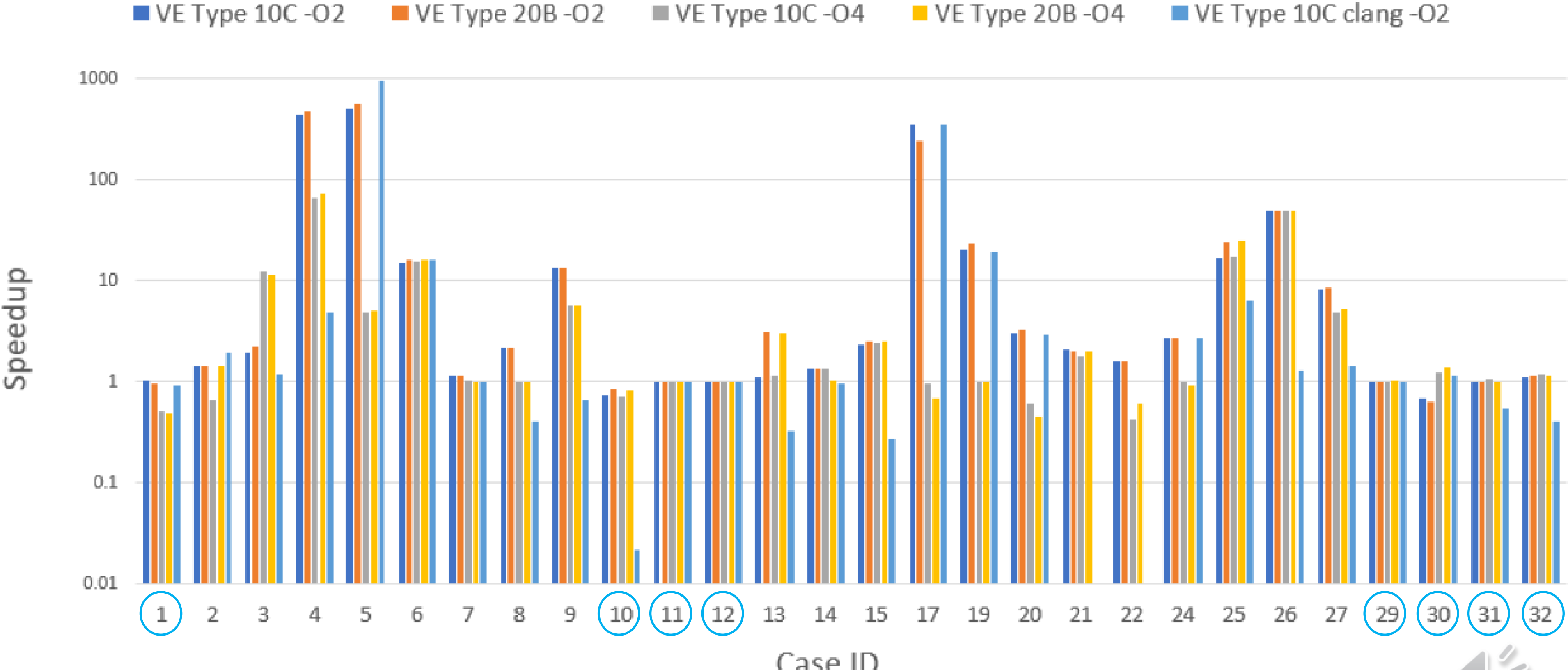
Evaluation : Effects of Compiler options

- Performance improves in
  - ncc -O4: 12 out of 28 techniques
- This is probably due to the more powerful compiler optimizations in -O4



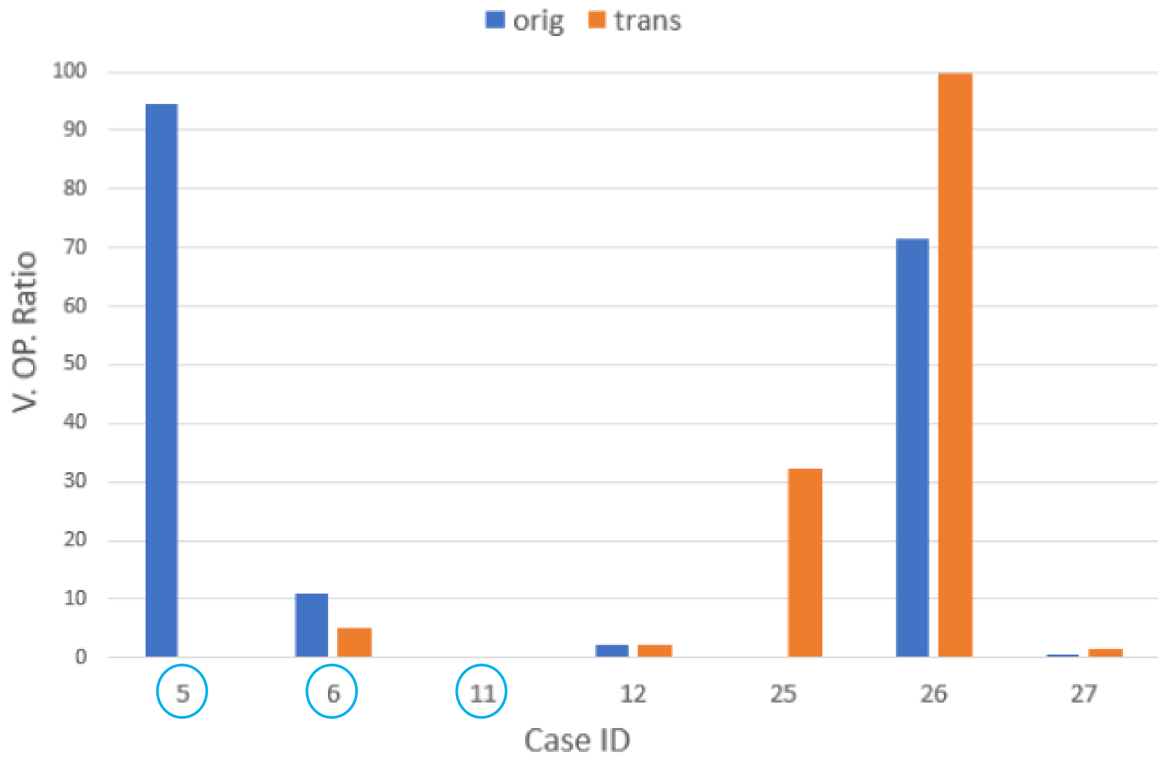
Evaluation : Performance difference in compiler

- In some cases, the performance is unchanged or decreased
- In LLVM-clang compiler, the performance degrades in more cases



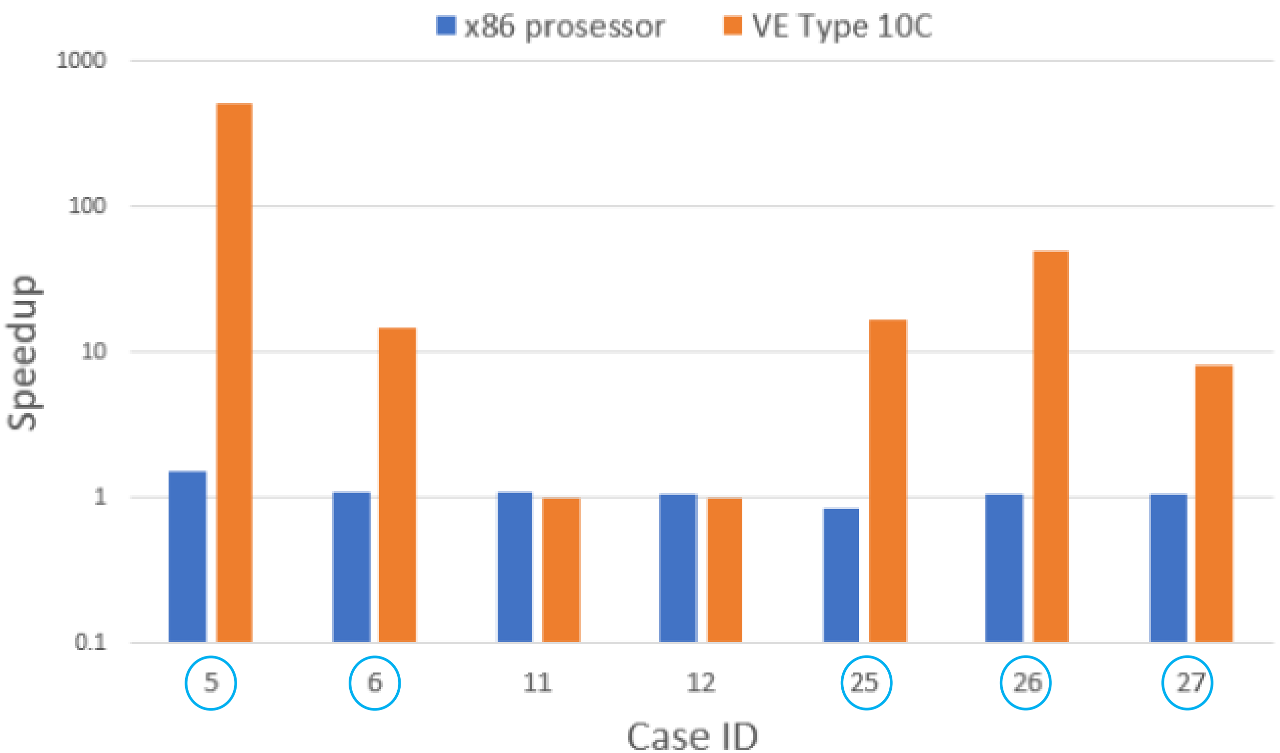
Evaluation ： Vectorization-aware loop optimization cases

- In Cases 5 and 11, compiler finds that the loops could be executed faster with scalar instructions
- In Case 6, the average vector length increases and the number of vector instructions decreases



Evaluation : compiling the performance tuning cases with gcc

- Most of vectorization-aware loop optimization techniques are not effective for the x86 processor



Conclusions

- This work empirically demonstrates
  - The performance tuning techniques for SX-9 and SX-ACE are still effective even for SX-AT with the C compiler
    - With a new compiler, some techniques are no longer effective
  - Performance tuning techniques for one system may not be effective for another system.
- Conclusions
  - Performance tuning expertise in the past is useful even for
    - Future system generations
    - New compilers
    - Other programming languages
  - But advances in compiler technology may outdate some.
  - The importance of separating system-specific optimization from application codes (= Xevolver's approach)