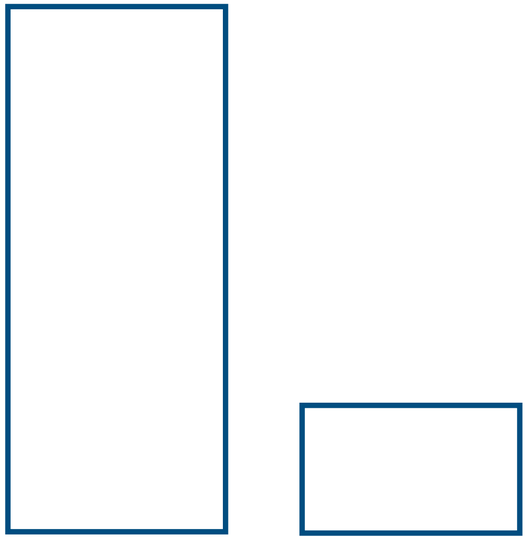
Reducing P4 Language's Voluminosity using Higher-Level Constructs



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P4 “suffers” from one significant limitation:

the voluminosity of the code

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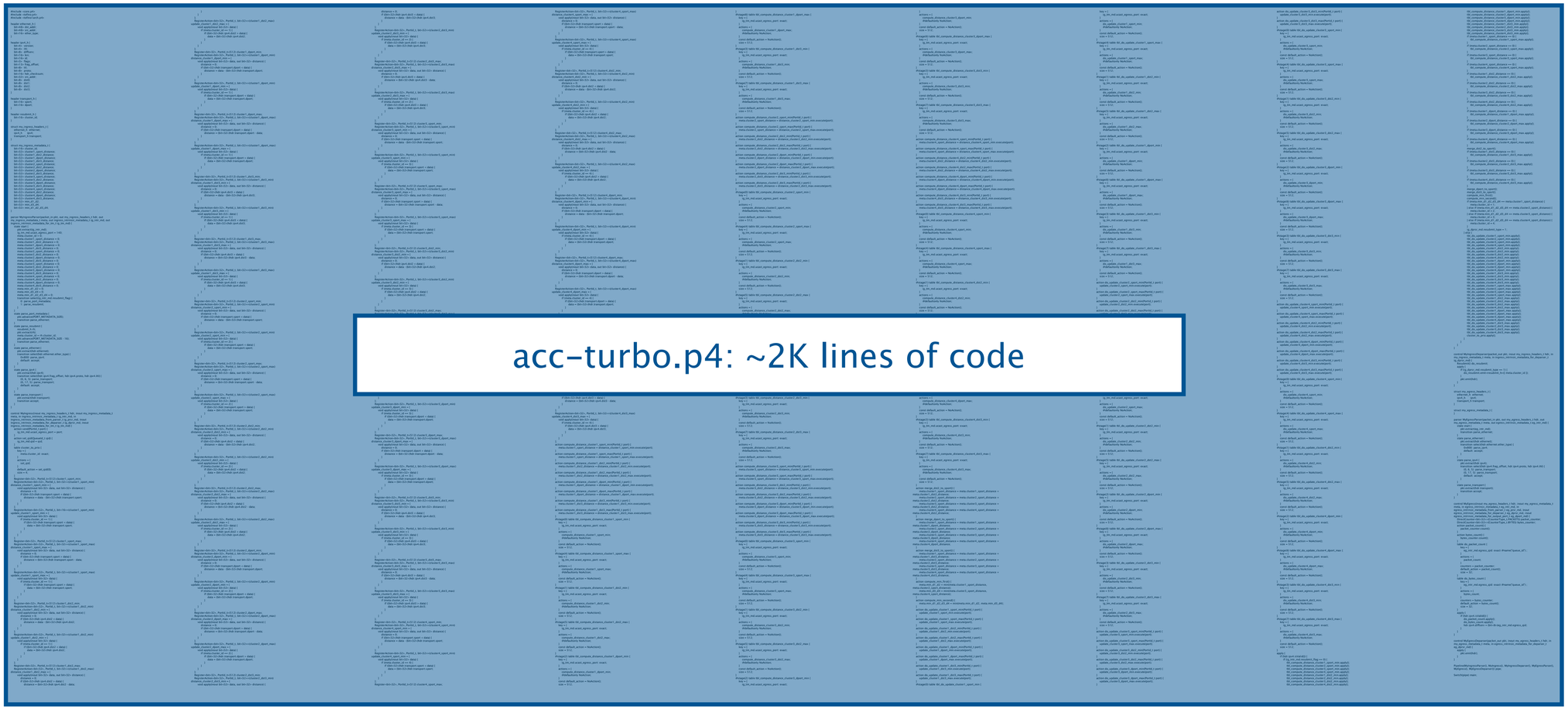

acc-turbo.p4: ~2K lines of code

P4’s voluminosity is due to two reasons:

verbosity and limited parametrization

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verbosity and limited parametrization

```
// P4 (tofino)
RegisterAction <... >(my_register) inc = {
     void apply (...) {
     val = val + 1;
     ...
     }
};

// C++
(* my_register)++;
```

P4's voluminosity is due to two reasons:

verbosity and limited parametrization

```
// P4

table my_table_0 {
    key = { field_0 : exact; }
    actions = { my_action; }
}

table my_table_1 {
    key = { field_1 : exact; }
    actions = { my_action; }
}

table my_table_2 {
    key = { field_2 : exact; }
    actions = { my_action; }
}
```

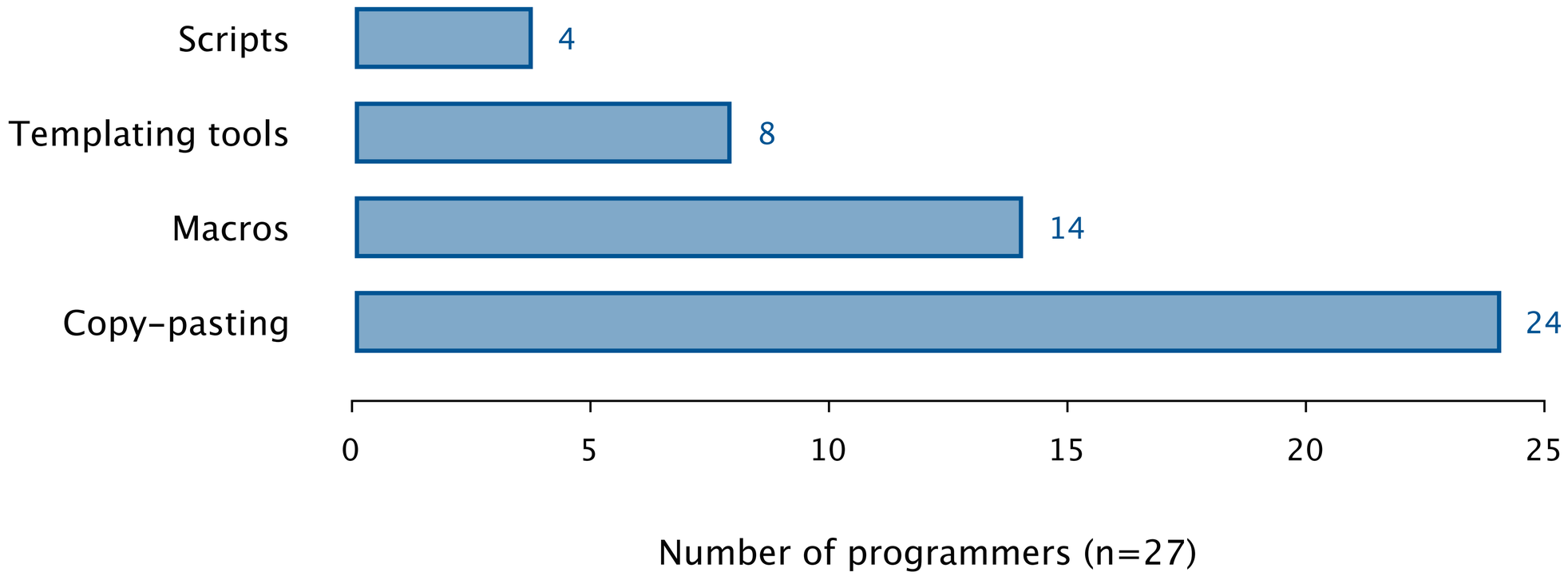
P4’s voluminosity makes it harder to write, debug, deploy, and maintain code

Voluminous code takes longer to process

Larger programs have higher probability of errors

Errors can propagate across code repetitions

P4 users rely on various tools to overcome the language voluminosity



Recent works have proposed

higher-level programming languages

Directly fitting P4 into target hardware	Lyra, Chipmunk, P4All
Adding macro-like annotations into P4	pcube

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higher-level programming languages

Directly fitting P4 into target hardware	Lyra, Chipmunk, P4All
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However, such languages …	extend expressivity
	lose fine-grained control

Can we reduce P4 language's voluminosity

by introducing higher-level constructs?

Can we reduce P4 language's voluminosity
by introducing higher-level constructs…

… *while preserving* … language expressivity, and
fine-grained control ?

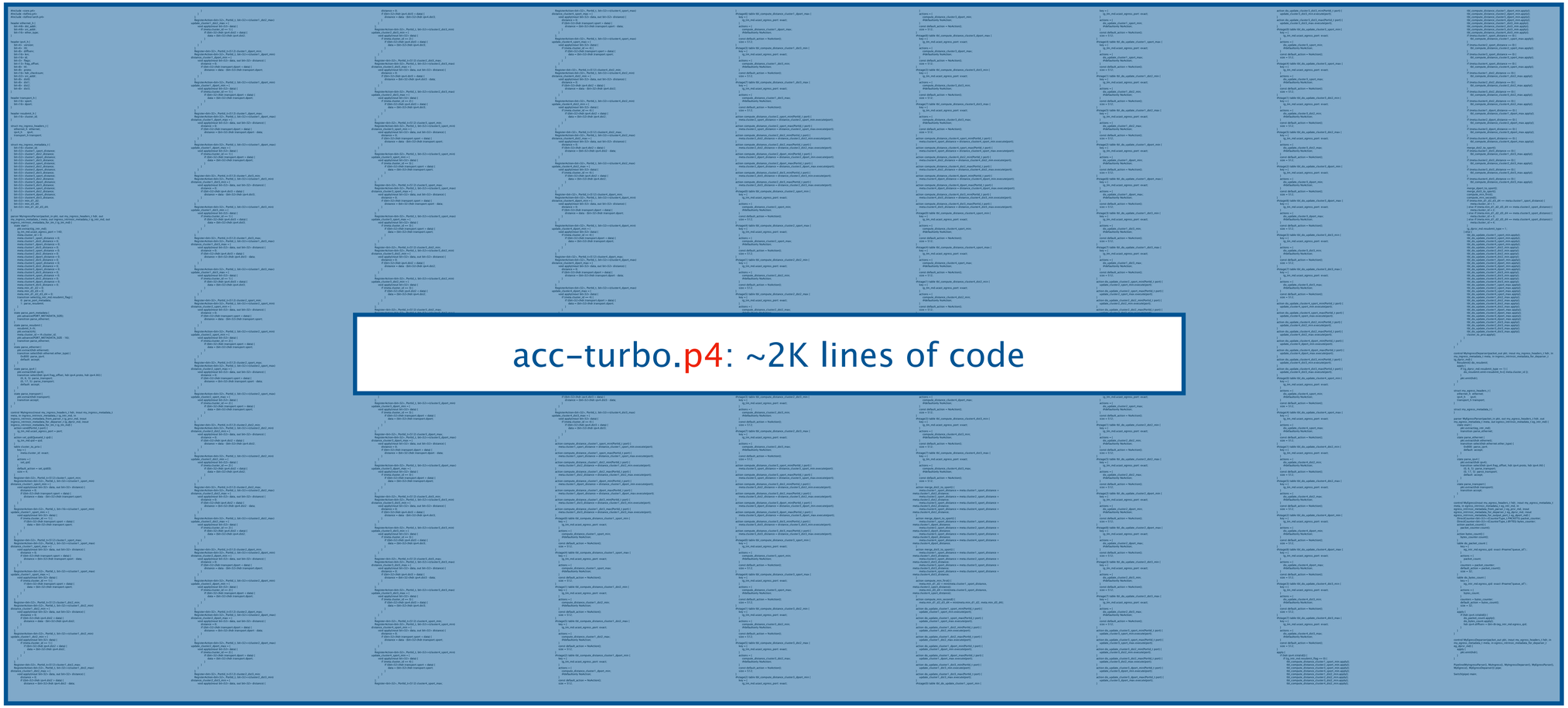
Yep!
Introducing 

O4 extends P4 with three simple constructs:

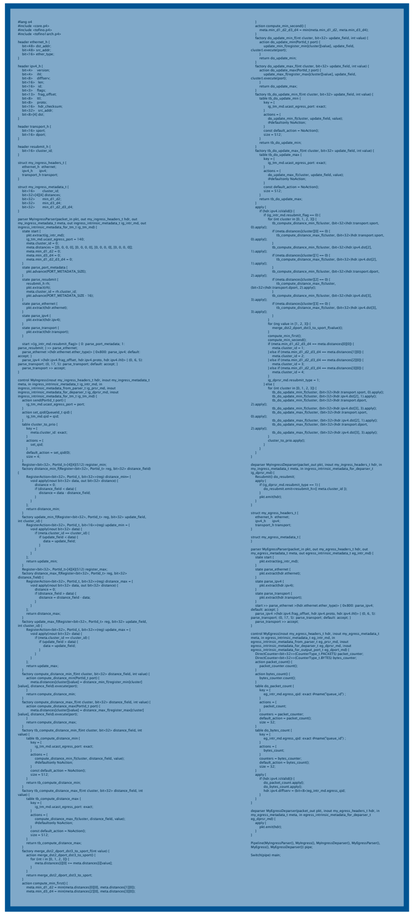
arrays, loops, and factories

Arrays	Group variables of the same type
Loops	Reduce code-block repetitions
Factories	Enable parametrization, “everywhere”

With O4, we go from this …



… to this



acc-turbo.o4: ~350 lines of code

O4 arrays group variables of the same type

```
// O4

bit<32>[2][2] my_array;



my_array = [[0, 1], [2, 3]];



my_array[0][0];
```

```
// P4

bit<32> my_array_0_0;
bit<32> my_array_0_1;
bit<32> my_array_1_0;
bit<32> my_array_1_1;


my_array_0_0 = 0;
my_array_0_1 = 1;
my_array_1_0 = 2;
my_array_1_1 = 3;


my_array_0_0;
```

O4 loops reduce repetitions of code-blocks

```
// O4

for (int index in [0,1,2,3]){
    my_call(index);
}
```

```
// P4

my_call(0);
my_call(1);
my_call(2);
my_call(3);
```

O4 factories enable parametrization in “any” P4 construct

```
// O4

factory my_factory (bit <8> field){

  table my_table {
    key = { field : exact; }
    actions = { my_action; }
  }
  return my_table ;

}

my_table_0 = my_factory (field_0);
my_table_1 = my_factory (field_1);
my_table_2 = my_factory (field_2);
```

```
// P4

table my_table_0 {
  key = { field_0 : exact; }
  actions = { my_action; }
}

table my_table_1 {
  key = { field_1 : exact; }
  actions = { my_action; }
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table my_table_2 {
  key = { field_2 : exact; }
  actions = { my_action; }
}
```
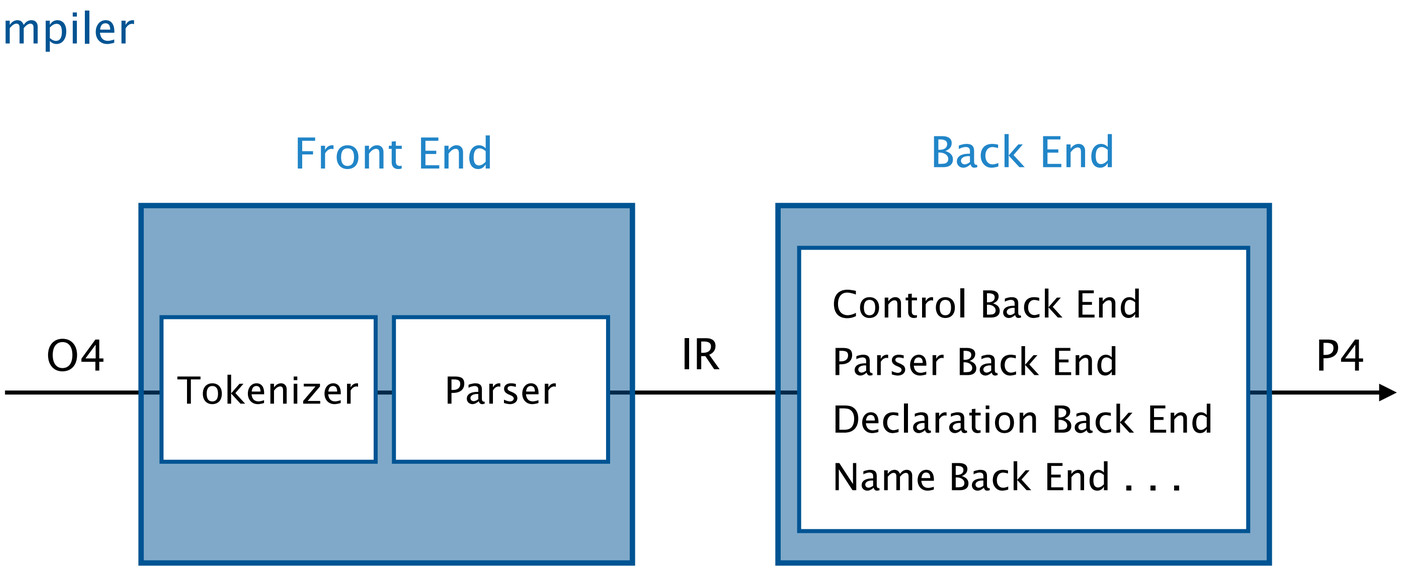

We implemented an O4 compiler using Racket



We evaluated O4 on several state-of-the-art P4 programs

We built a dataset of p4-16 programs

Open Tofino and P4-Learning (AES, Conquest, ACC-Turbo…)

v1model and *tna* architectures

We evaluated …

… voluminosity reduction

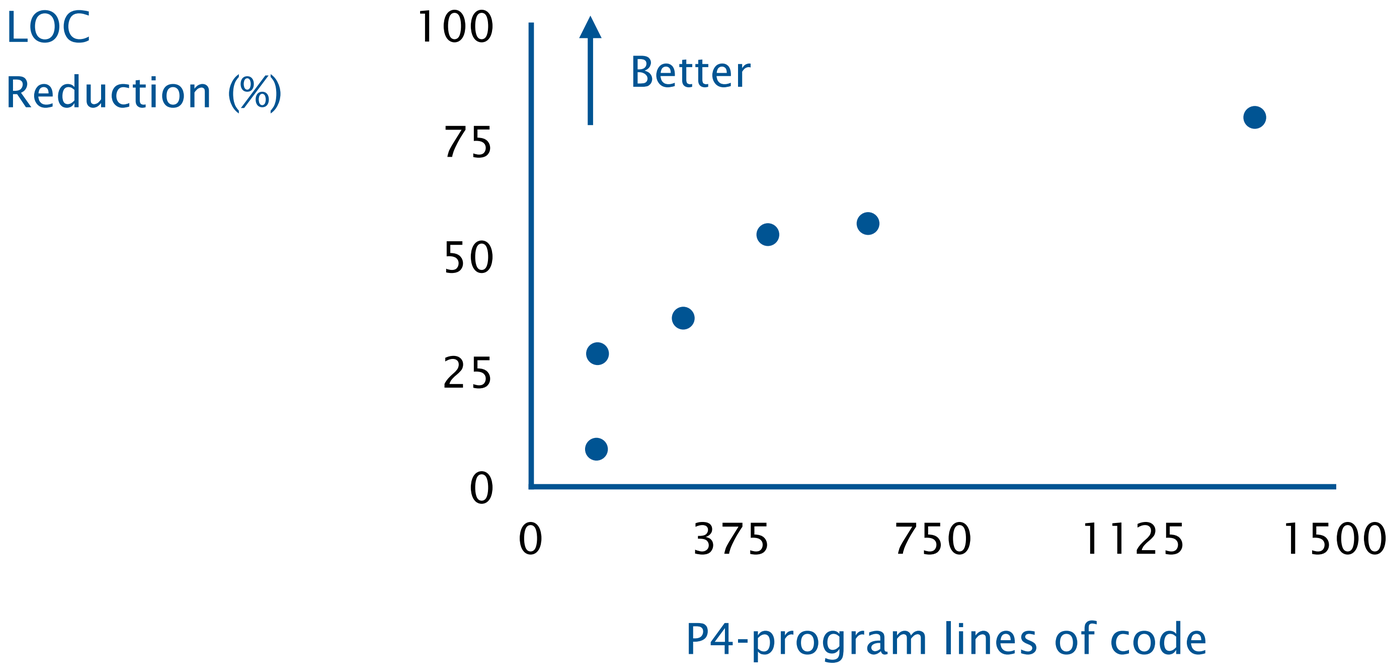
… verbosity reduction

… code-clone reduction

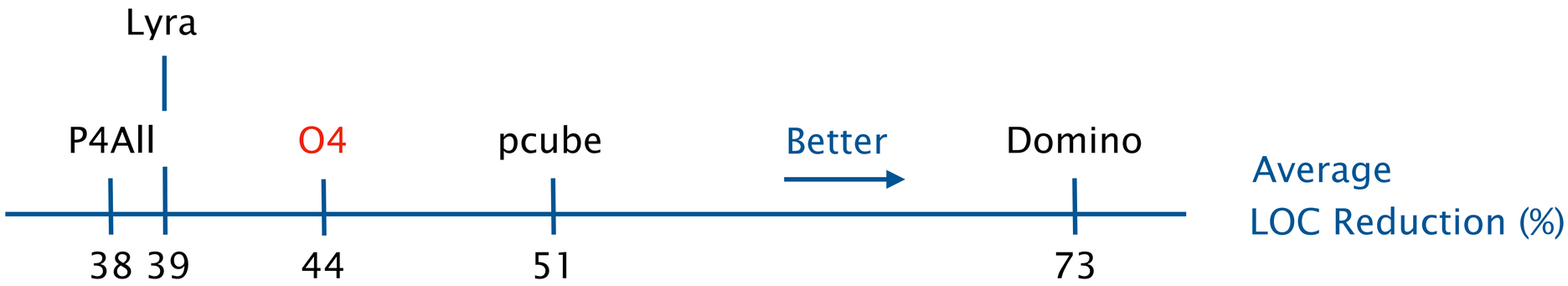
We evaluated O4 on several state-of-the-art P4 programs

Results		
	Volume	-42.4%
	Verbosity	-32.6%
	Number of Clones	-56.3%

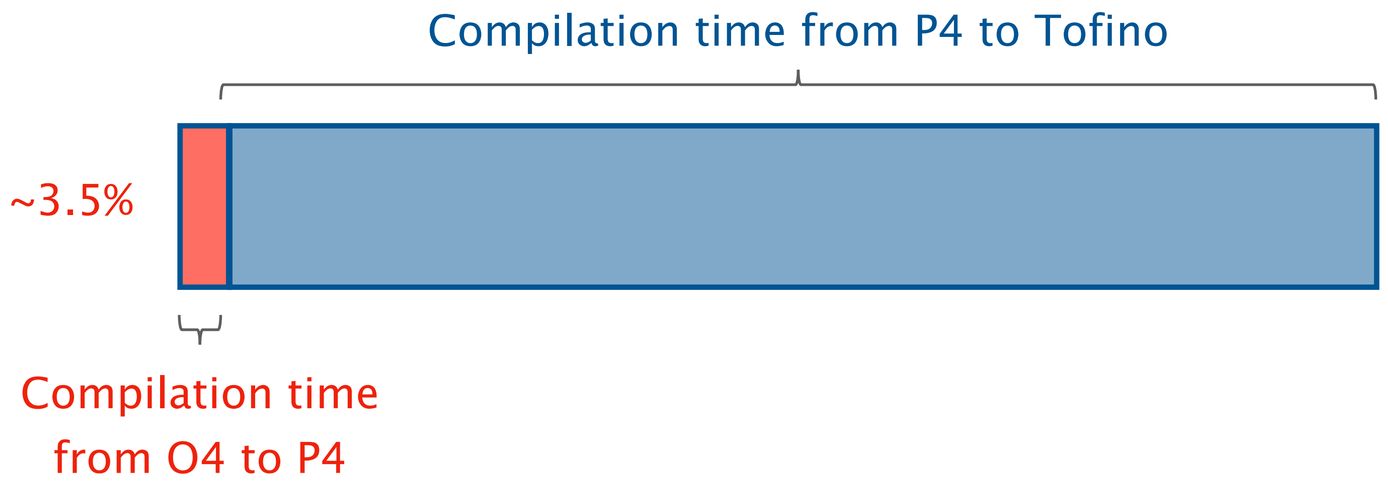
O4 performs better for larger programs



O4 performs similarly to state-of-the-art higher-level programming languages



The O4 compiler is fast



Reducing P4 Language's Voluminosity using Higher-Level Constructs

P4 language is highly voluminous

usually requiring thousands of lines of code

O4 introduces three high-level constructs

arrays, loops, and factories

O4 significantly decreases code volumes

preserving expressivity and low-level control

github.com/nsg-ethz/O4