Automatic Test Case Reduction for OpenCL

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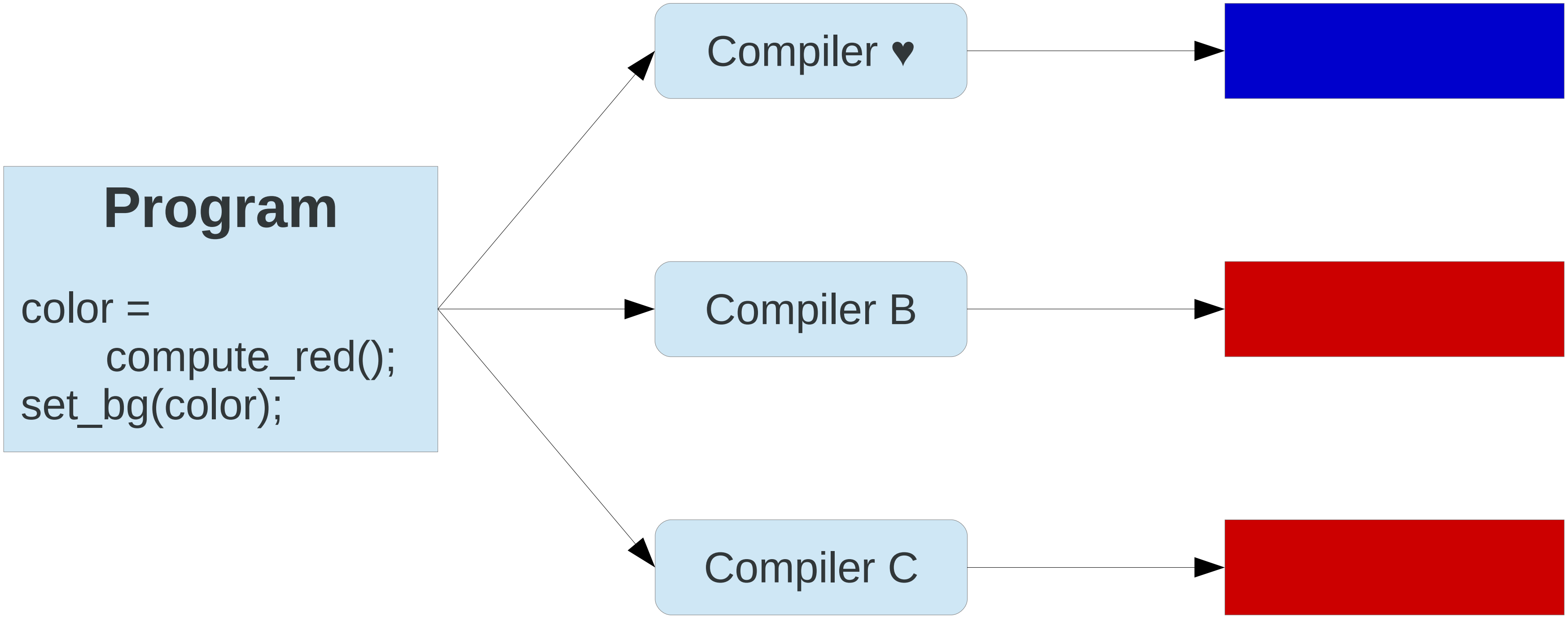
Reporting a compiler bug



Program

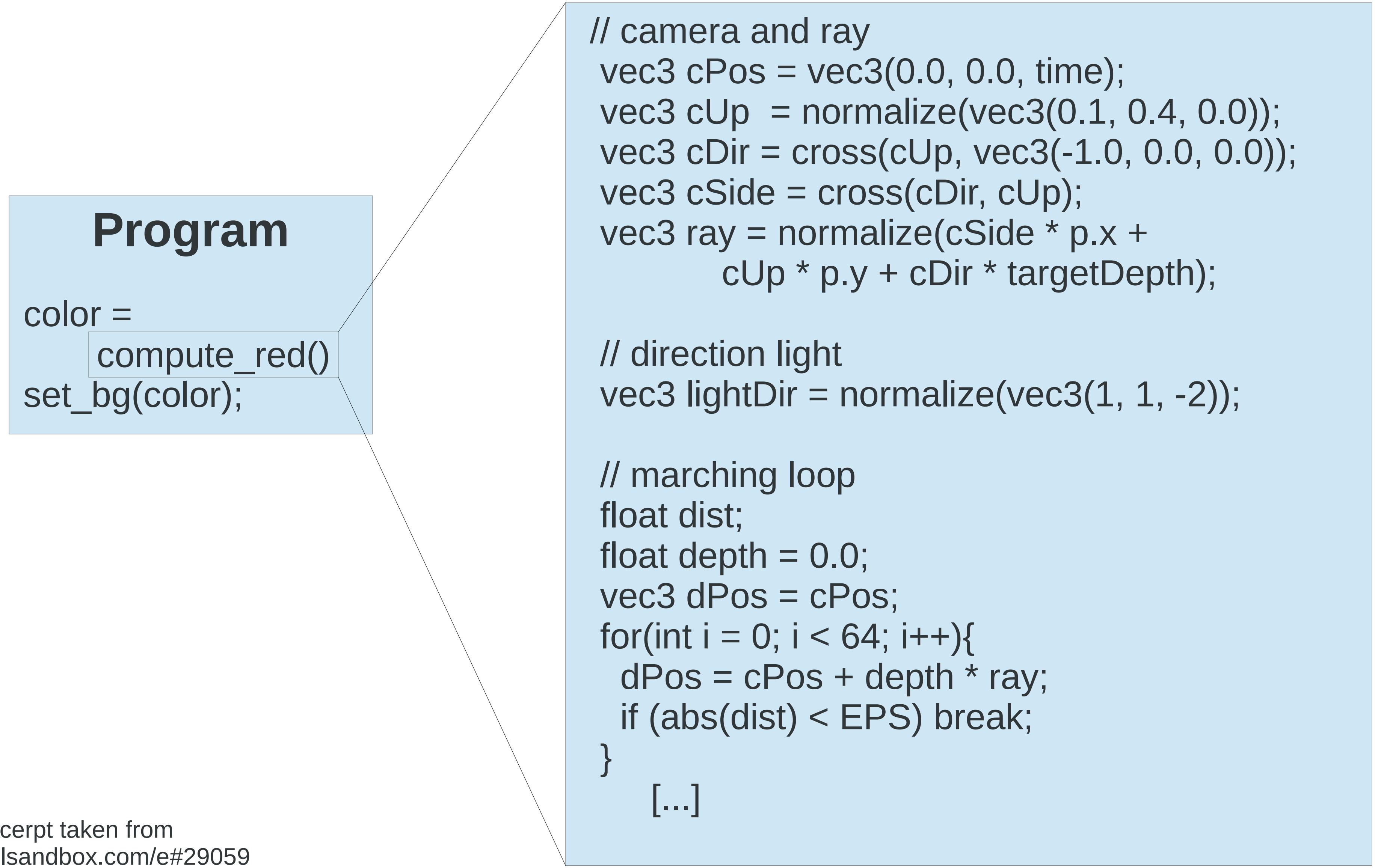
```
color =
        compute_red();
set_bg(color);
```

Compiler ♥

Compiler B

Compiler C

Reporting a compiler bug



Program

```
color =
      compute_red()
set_bg(color);
```

```
// camera and ray
 vec3 cPos = vec3(0.0, 0.0, time);
 vec3 cUp  = normalize(vec3(0.1, 0.4, 0.0));
 vec3 cDir = cross(cUp, vec3(-1.0, 0.0, 0.0));
 vec3 cSide = cross(cDir, cUp);
 vec3 ray = normalize(cSide * p.x +
             cUp * p.y + cDir * targetDepth);

 // direction light
 vec3 lightDir = normalize(vec3(1, 1, -2));

 // marching loop
 float dist;
 float depth = 0.0;
 vec3 dPos = cPos;
 for(int i = 0; i < 64; i++){
   dPos = cPos + depth * ray;
   if (abs(dist) < EPS) break;
 }
      [...]
```

Code excerpt taken from
http://glslsandbox.com/e#29059

Reporting a compiler bug

Excerpt from a CLsmith*-generated kernel

```
                    for (p_2718->g_197 = 0; (p_2718->g_197 < 51); p_2718->g_197 =
safe_add_func_int64_t_s_s(p_2718->g_197, 4))
                    { /* block id: 242 */
                        int16_t *l_445 = (void*)0;
                        int16_t **l_444[6][4] = {{&l_445,&l_445,(void*)0,&l_445},{&l_445,&l_445,
(void*)0,&l_445},{&l_445,&l_445,(void*)0,&l_445},{&l_445,&l_445,(void*)0,&l_445},{&l_445,&l_445,
(void*)0,&l_445},{&l_445,&l_445,(void*)0,&l_445}};
                        int16_t ***l_443 = &l_444[2][2];
                        int i, j;
                        (*l_437) = p_60;
                        p_2718->g_446 = ((*l_443) = (void*)0);
                    }
                }
            }
            (*l_467) ^= (0x68097A9AF58B0784L | ((safe_div_func_uint64_t_u_u((l_433 ,
(safe_unary_minus_func_int16_t_s((safe_sub_func_int32_t_s_s((p_61 ==
((safe_mod_func_uint8_t_u_u((l_422 != ((*l_457) = &l_314[3])),
((safe_lshift_func_int16_t_s_u((((((*l_460)--) && (safe_lshift_func_uint8_t_u_s((p_61 , p_2718-
>g_167[9][3]), ((safe_rshift_func_uint16_t_u_u(0xA1B0L, (((void*)0 != &p_2718->g_446) < 1UL))) |
p_2718->g_216)))) , l_375) , p_61), 10)) ^ p_2718->g_234.f2.f1))) >= p_2718->g_216)), l_319))))), 1L))
== 1UL));
            if ((*p_60))
                break;
        }
```

* *Many-core Compiler Fuzzing.* Lidbury et al., PLDI'15.

Overview

- Creduce
- Lifting Creduce to OpenCL
- ShadowKeeper
- Experimental evaluation
- Future work
- Closing remarks

Creduce

(*Test-case reduction for C compiler bugs*. Regehr et. al, PLDI'12)

```
int foo (int x) {
  int y = 3;
  int a[20];
  for (int i = 0; i <= 20; i++)
    a[i] = i;
  if (x+y < 20)
    return a[x+y];
  return a[19];
}
```

Creduce

(*Test-case reduction for C compiler bugs*. Regehr et. al, PLDI'12)

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int f~~oo (int x) {~~
    ~~int y = 3;~~
    ~~int a[20];~~
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Creduce

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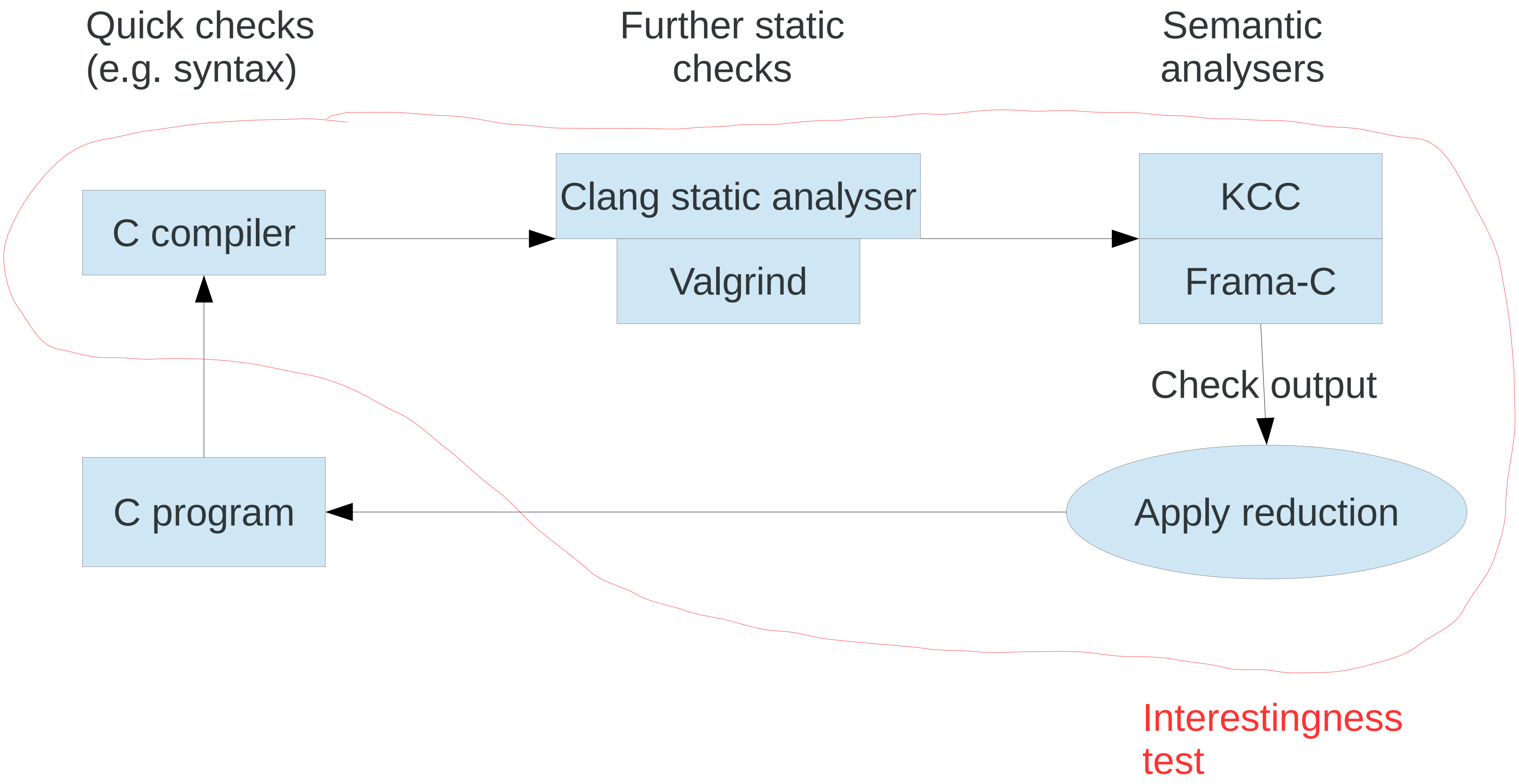

Creduce

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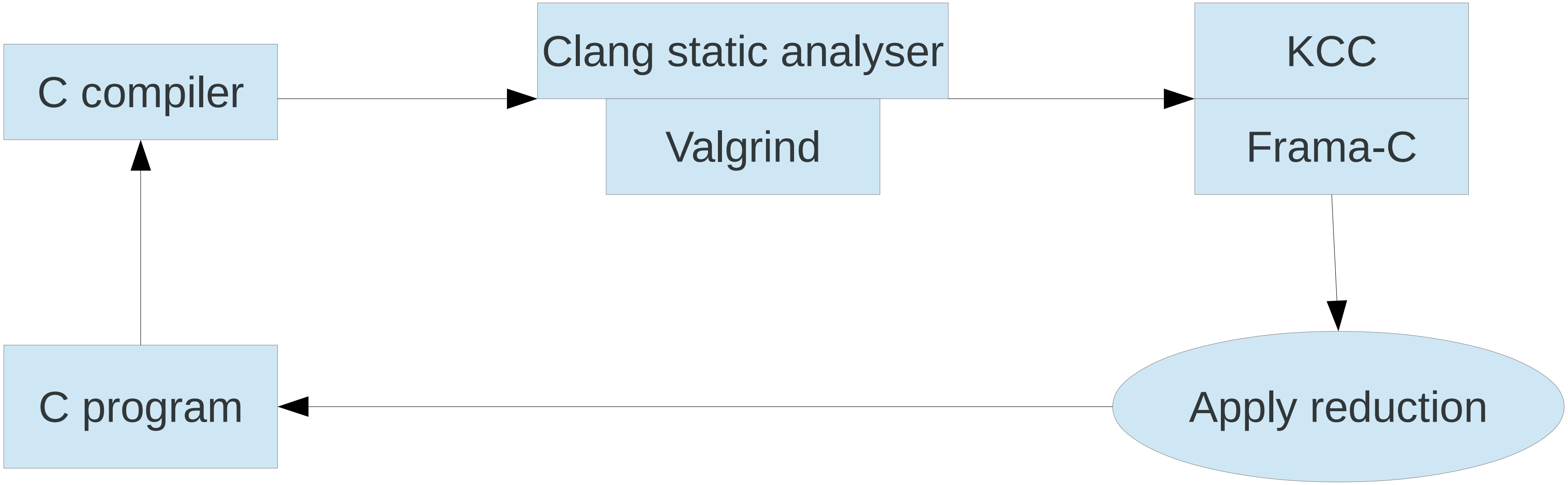
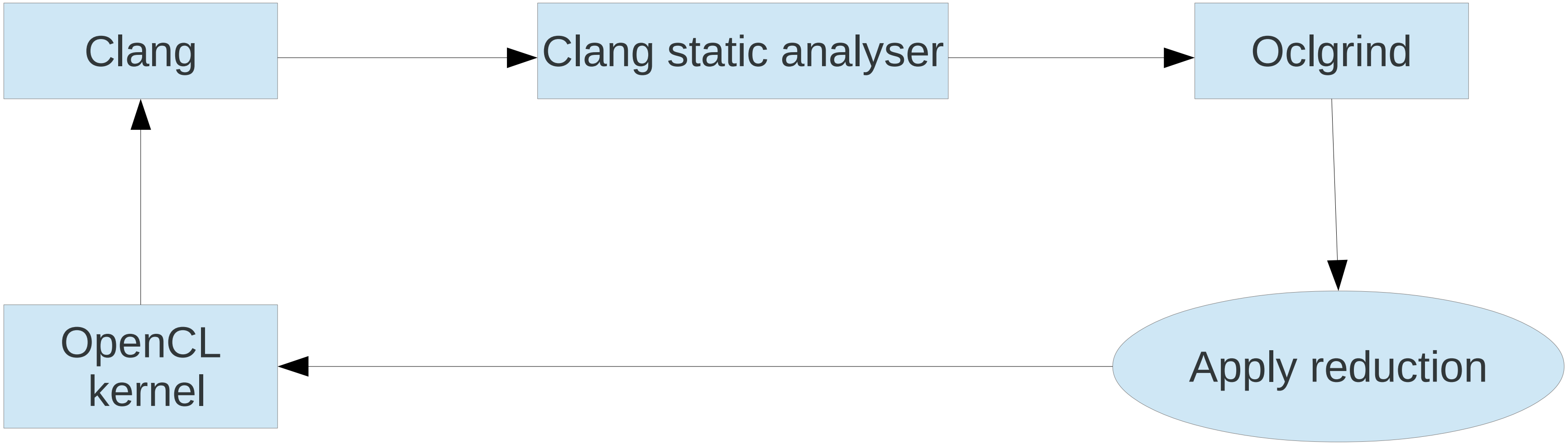


Lifting Creduce to OpenCL



Custom tailored based on CLsmith*-generated kernels

* *Many-core Compiler Fuzzing.* Lidbury et al., PLDI'15.

Lifting Creduce to OpenCL

- New bugs
  - data races
  - barrier divergence
- New tools
  - Oclgrind

Lifting Creduce to OpenCL

jrprice/Oclgrind

- Modular OpenCL emulator
- Checks for multiple types of errors in kernels
  - data races
  - uninitialized variables

ShadowKeeper

- Oclgrind's former uninitialized value detection plugin was insufficient
- Conceptually based on Valgrind's *Memcheck* and Clang's *MemorySanitizer*
- Strives for bit level accuracy, except when it would greatly impact performance

ShadowKeeper

Technical details

- Real operations simulated in *shadow memory*
- Shadow memory contains definedness of each bit of real memory
- Propagate definedness along shadow operations

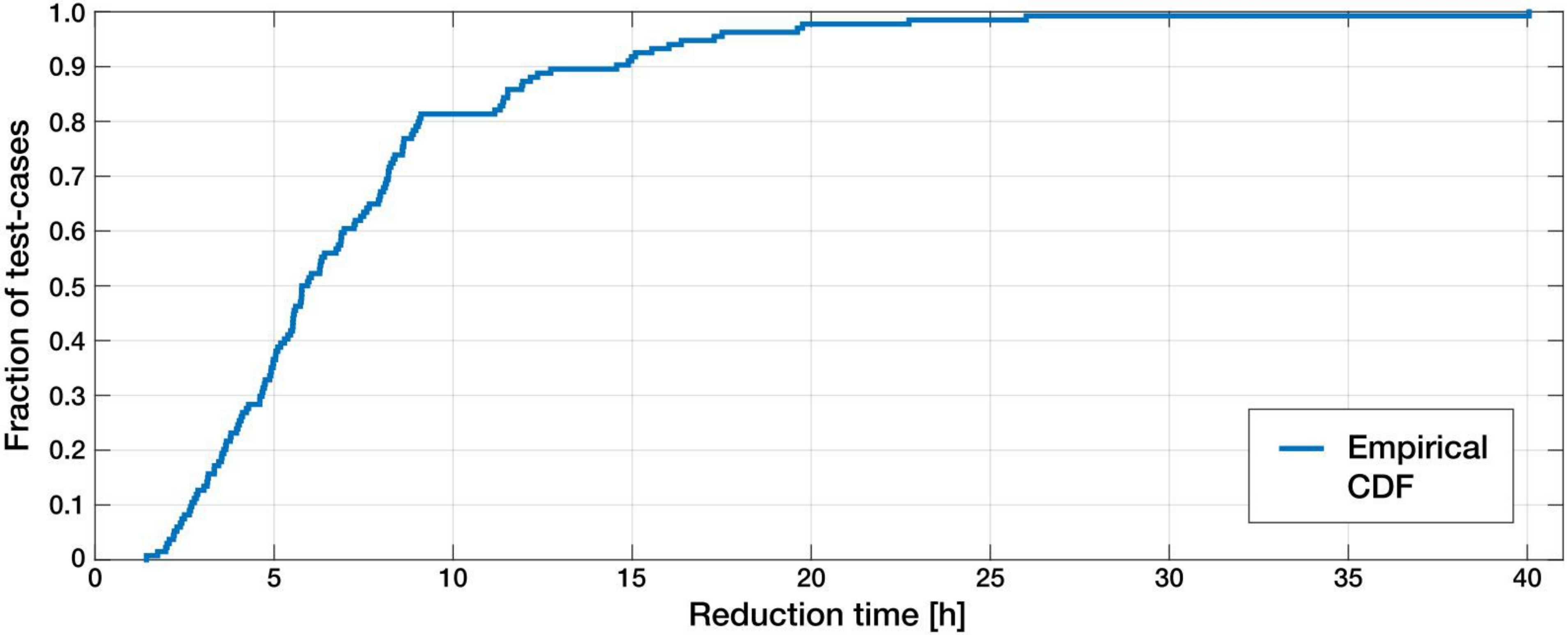
Experimental evaluation

Setup

- 5 OpenCL devices
- 127 kernels yielding different results between optimised and not optimised compilation
- 272 automatic reductions

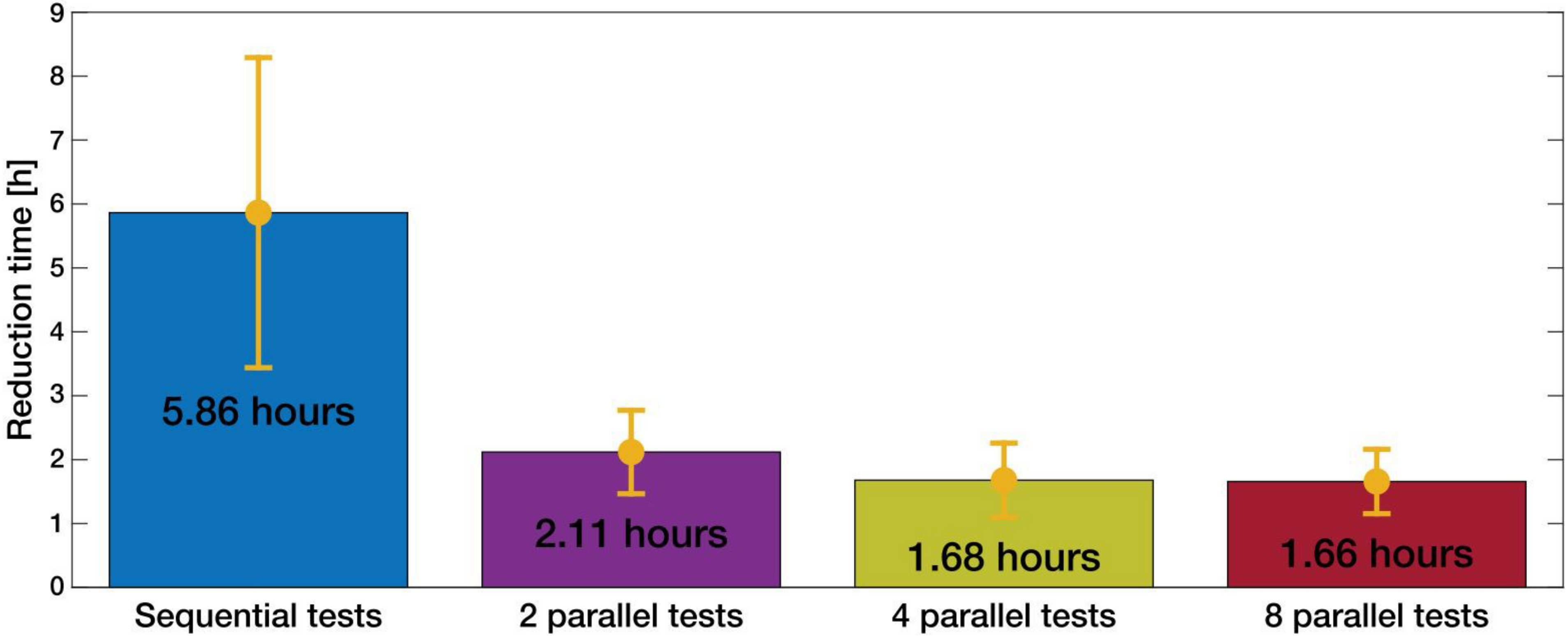
Experimental evaluation

CDF of reduction times



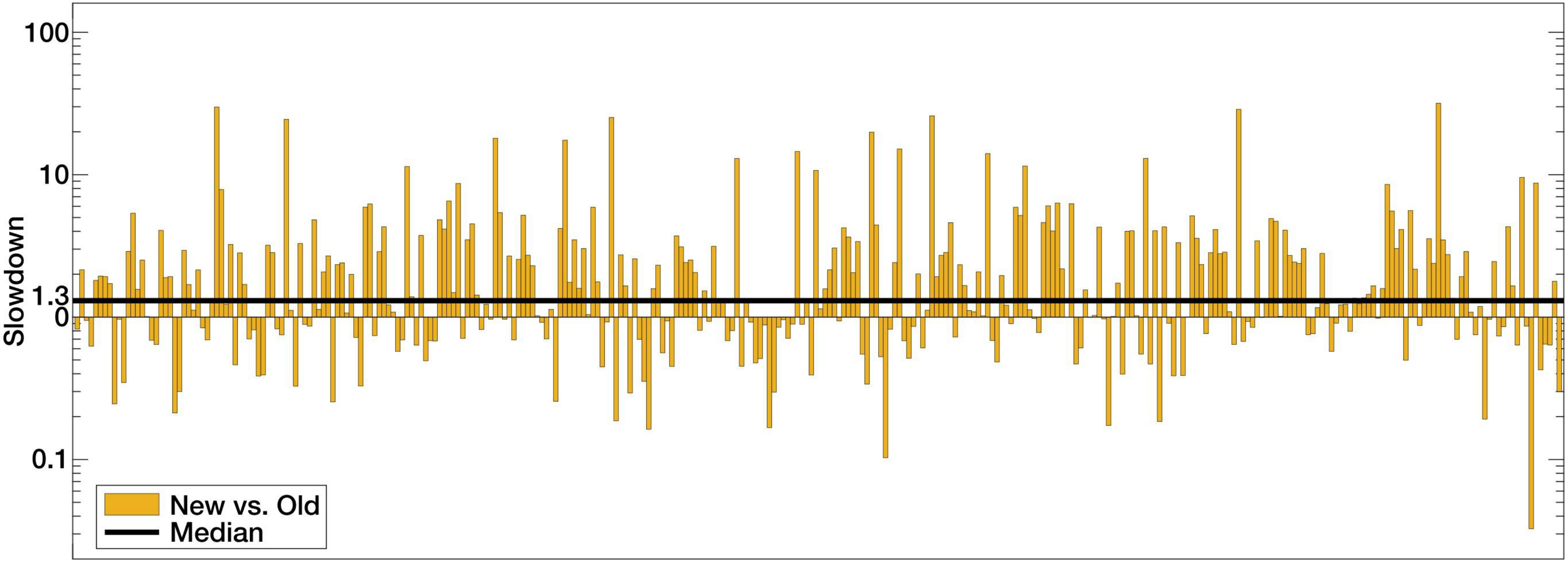
Experimental evaluation

Comparison of average times for multiple parallel tests



Experimental evaluation

ShadowKeeper versus Old plugin



Future work

- Usability improvements
- Improve reduction time
- Bug analysis

Closing remarks

- Lifted the Creduce framework to OpenCL
- Using a small amount of human time, can find reasonably small kernels presenting compiler bugs
- Improved Oclgrind, including developing a new uninitialized value detection plugin

Thank you!

Questions?

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