



Finding Compiler Bugs with Random Testing

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A GCC Bug

```
int g[1];
int *p = &g[0];
int *q = &g[0];

int main(void)
{
  g[0] = 1;
  *p = 0;
  *p = *q;
  printf("%d\n", g[0]);
}

End result of g[0]:
Expected: 0
GCC: 1
```

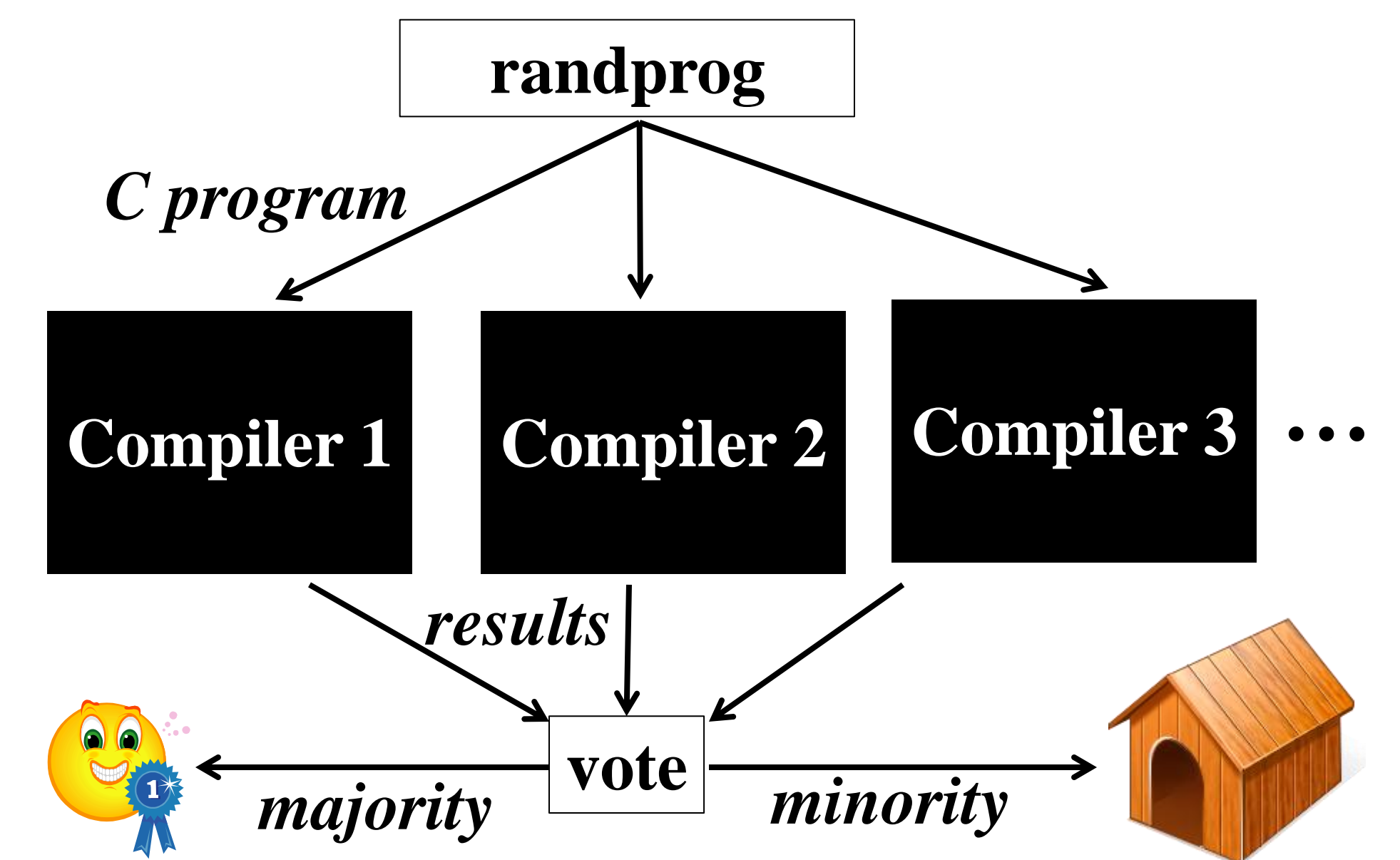
A LLVM Bug

```
short g, i ;
void f()
{
  short l[5];
  for (i=0; i<1; i++)
    l[i] = 0;
lbl:
  l[0] ^= 1;
  assert(&g != 0);
  goto lbl;
}

Compiler Crashed
```

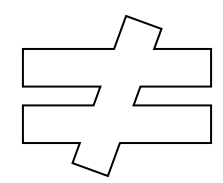
randprog - the tool

- A random C program generator
- Detects incorrectness of compilers by voting
- We used it to find numerous compilers bugs



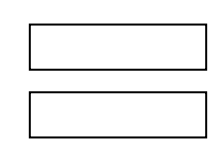
Good Vs Bad Programs

A program that can be compiled



Good program

A program can be compiled And Has **ZERO** undefined or unspecified behavior



Good program

Undefined behavior (such as divide by 0) or unspecified behavior (such as order of evaluation) gives compilers freedom to diverge, causing failure to our voting mechanism

Bad program example

```
int f(void)
{
  int a[5];
  int i, j;
  int* p;

  a[0] = *p; // dead pointer dereference
  j = 6;
  a[j] = 5; // array index out of bound
  goto lbl;
  p = &j;
lbl:
  a[1] = *p; // Jump over variable initialization
}

```

The work behind the scene that avoids generating bad programs in randprog

Pointer Analysis

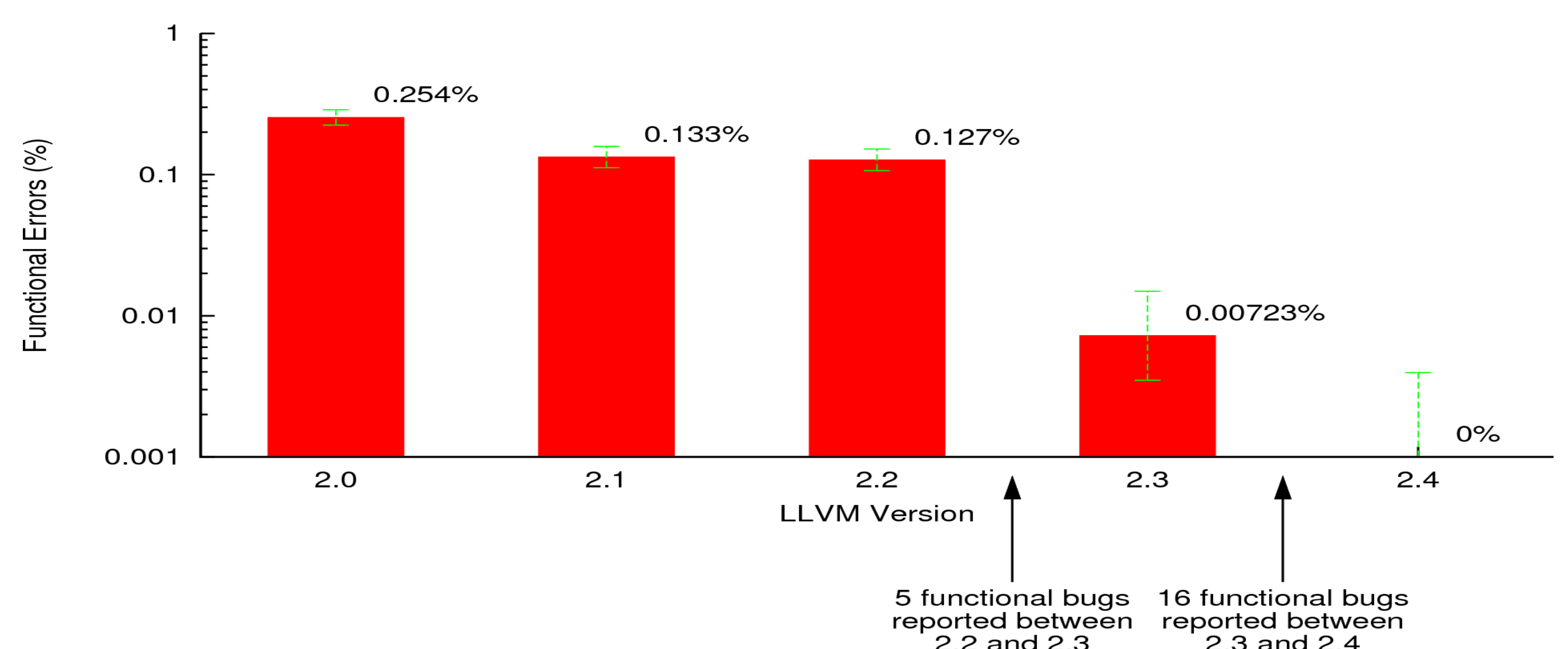
- a context-sensitive flow-sensitive inter-procedural point-to analyzer
- tracks the point-to relationship between variables. For example:
 $x = \&y \Rightarrow x \rightarrow \{y\}$
- the analysis is performed on-the-go after each statement generation
- randprog consults the analyzer to avoid null/dead pointer dereferencing

Control Flow Analysis

- a control flow analyzer that can handle abnormal edges created by jump statements (goto / break / continue)
- Preemptively analyze possible effects a new jump statement would cause, and reject it if undefined behavior is introduced
- Backward jumps are treated as loop creator. Possible undefined behaviors are identified after a fixed point analysis

Out-of-bound array indexing is avoided by taking modulo

How we helped a compiler to be more reliable



Functional Errors we found in LLVM