

Divergent Representations: When Compiler Optimizations Enable Exploitation

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Common: 45% of scanned projects.

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add eax, 1;  
lea rcx, [rdi + 1];  
cmp byte ptr [rdi], sil;  
mov rdi, rcx;  
jne
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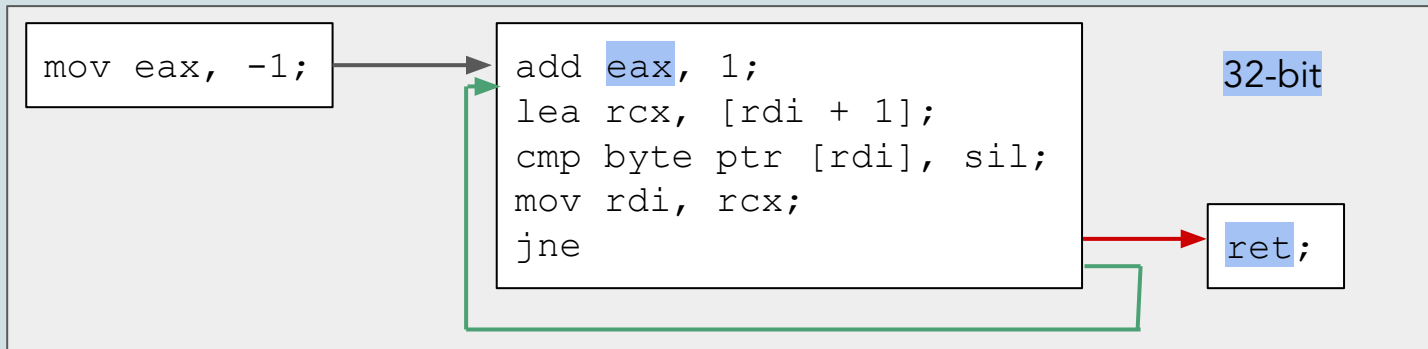
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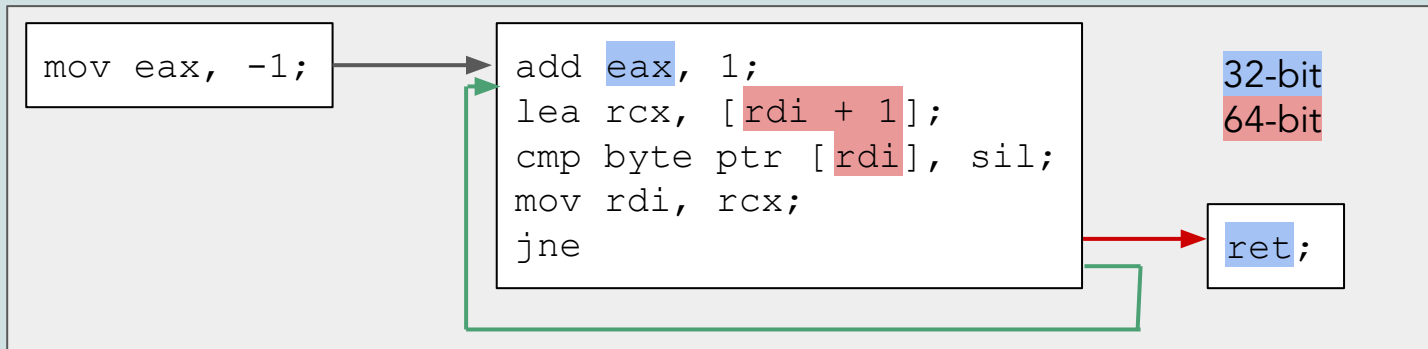


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If `i` overflows: divergent values

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32-bit
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Previous work [1,2] showed:

compiler optimizations + undefined behavior = unexpected vulnerabilities

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if (buf + i < buf)
    return;
buf[i] = '\\0';
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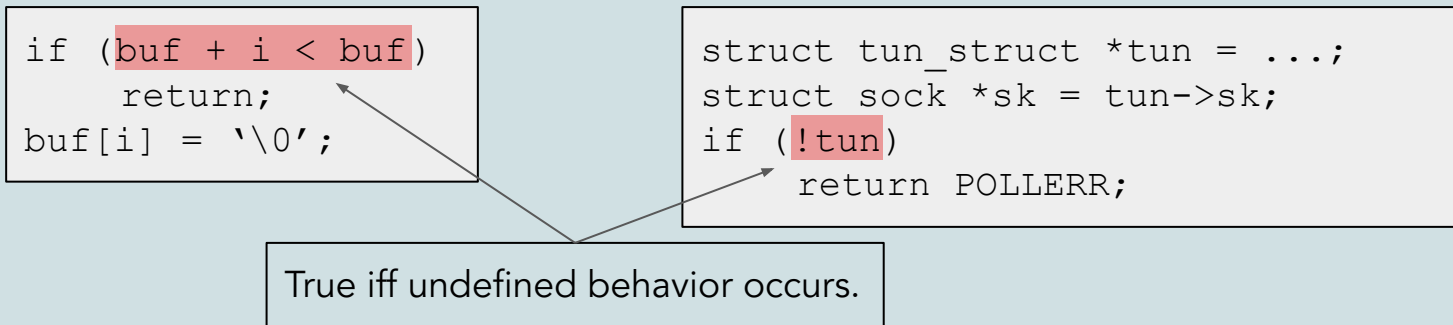
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struct tun_struct *tun = ...;
struct sock *sk = tun->sk;
if (!tun)
    return POLLERR;
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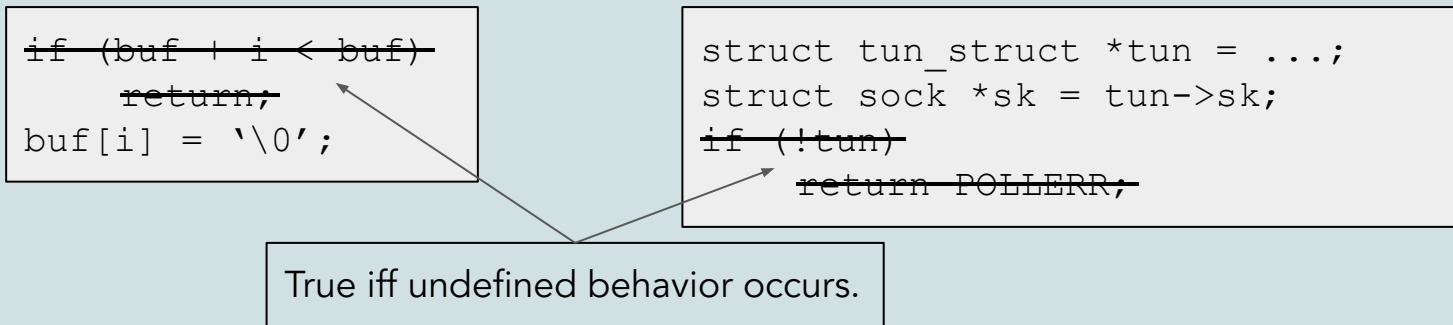


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This work: benign patterns in compiled code to exploit existing vulnerabilities.

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Similar to ROP gadgets.

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Conditions only satisfiable because of a divergent representation.

Case Study: SQLite divrep helps exploit buffer overflow

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int len, nspecial;
char output[BUF_SIZE];

for (i=0; input[len] != '\\0'; len++) {
    if (input[len] == quote) nquotes++;
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if (len + nquotes <= BUF_SIZE)
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1. **Scan** input string: count quotes and total number of bytes.

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Key insight: increment len with different semantics to meet conditions.

E.g., avoid negative memory offsets by using unicode characters to increment len with 64-bit semantics whenever a 32-bit value is undesirable.

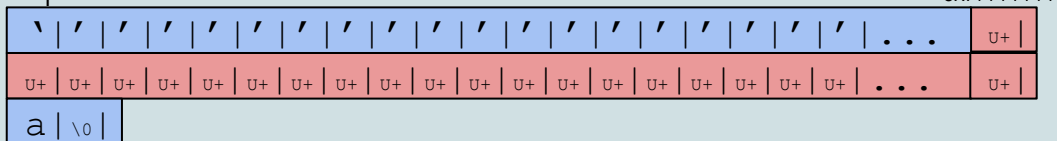
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input



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```
(gdb) info frame
Stack level 0, frame at 0x7ffd3b5468b0:
rip = 0x7f1a2c35ff09 in sqlite3_str_vappendf (sqlite3.c:27504);
saved rip = 0xdeadbeefdeadbeef
```

*Canaries not considered.

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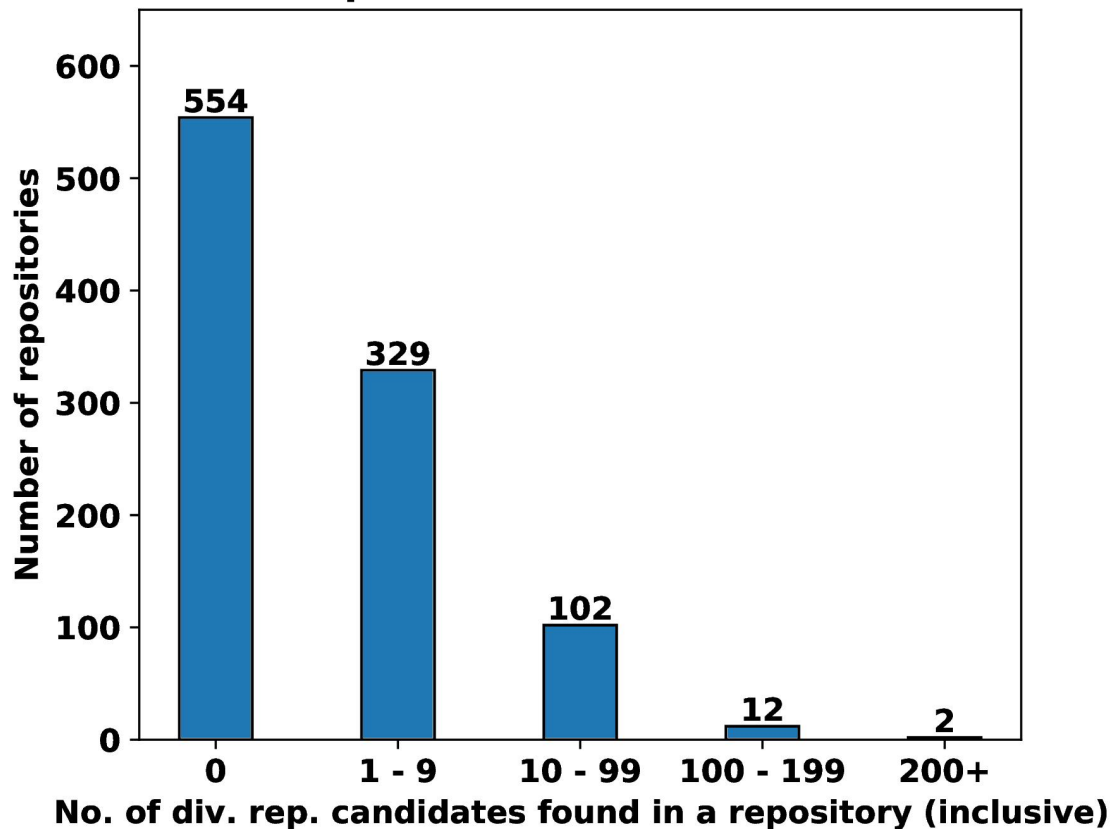
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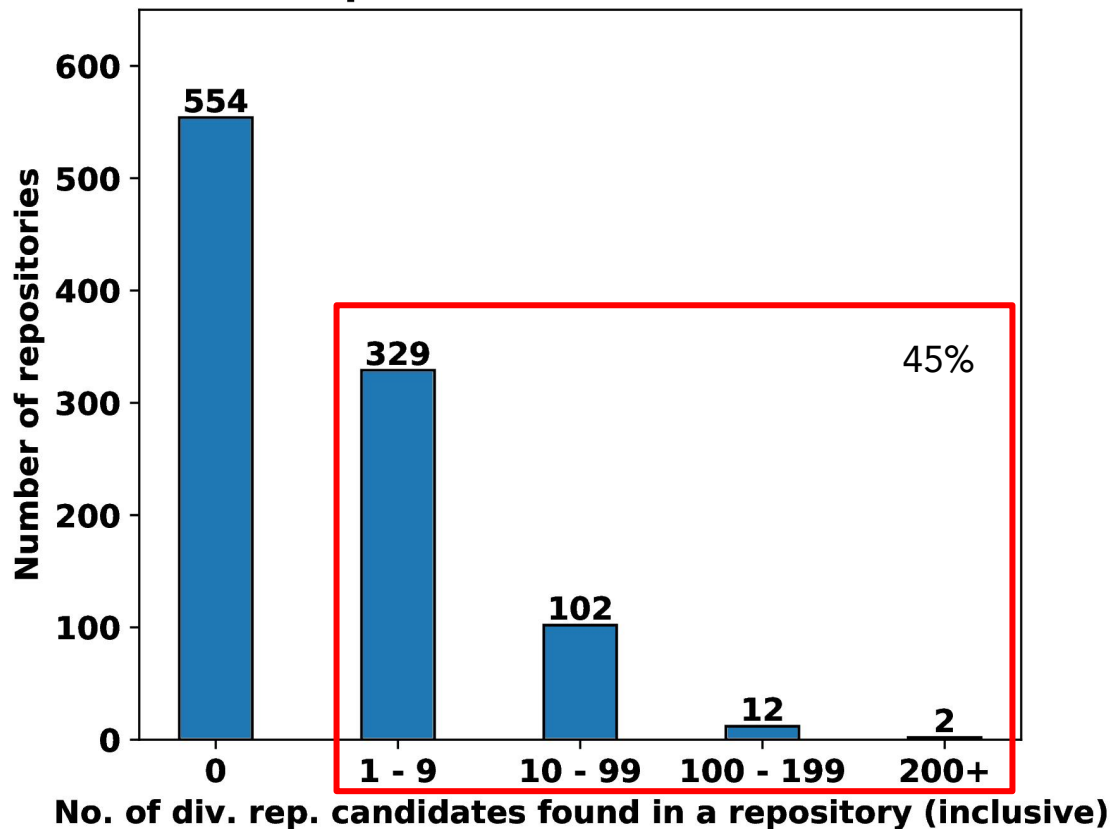
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Counts are under-approximations: other forms of divergent representations may exist.

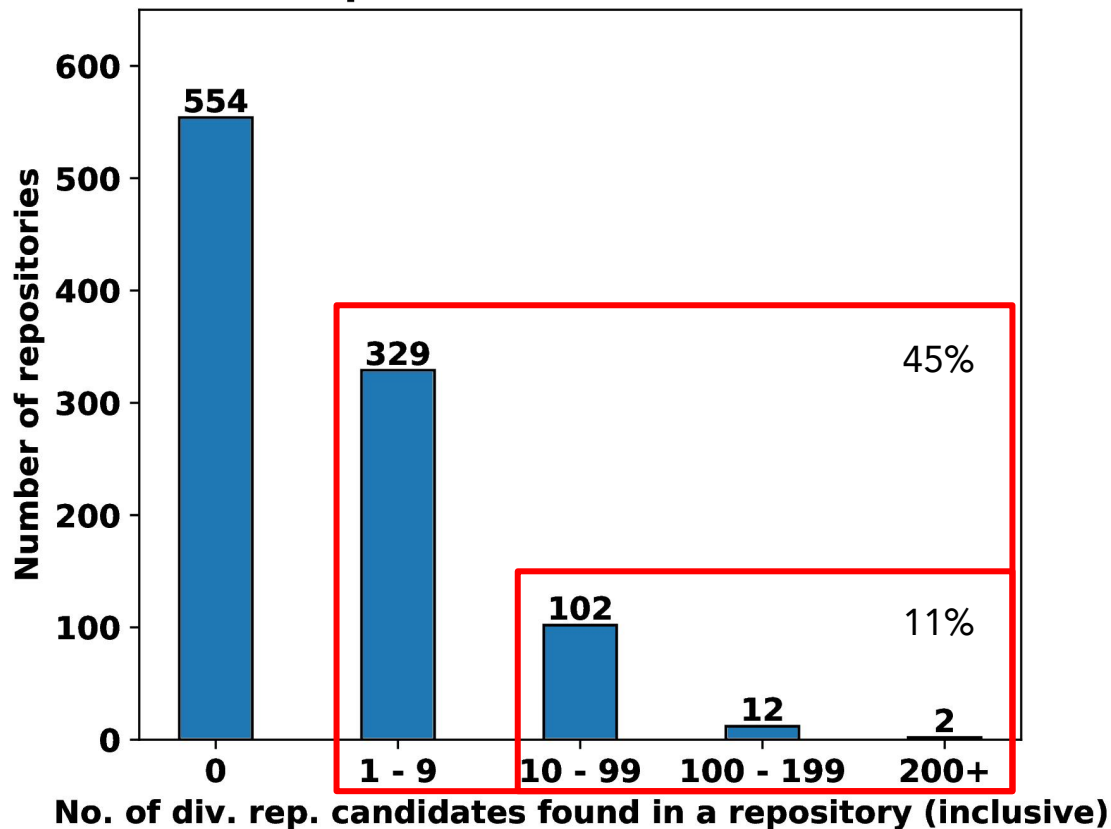
Distribution of Source Code Divergent Representation Candidates



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libsqlite3.so: # of divergent representations in compiled program

Optimization Level	Clang	GCC
-O0	0	0
-O1	23	33
-O2	26	37
-O3	30	53

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Our tools should reason about divergent representations:

- Source code: linters
- Binary: decompilers

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- Must understand causes and risks.
- Ought to prevent when acceptable.