SEAN HEELAN

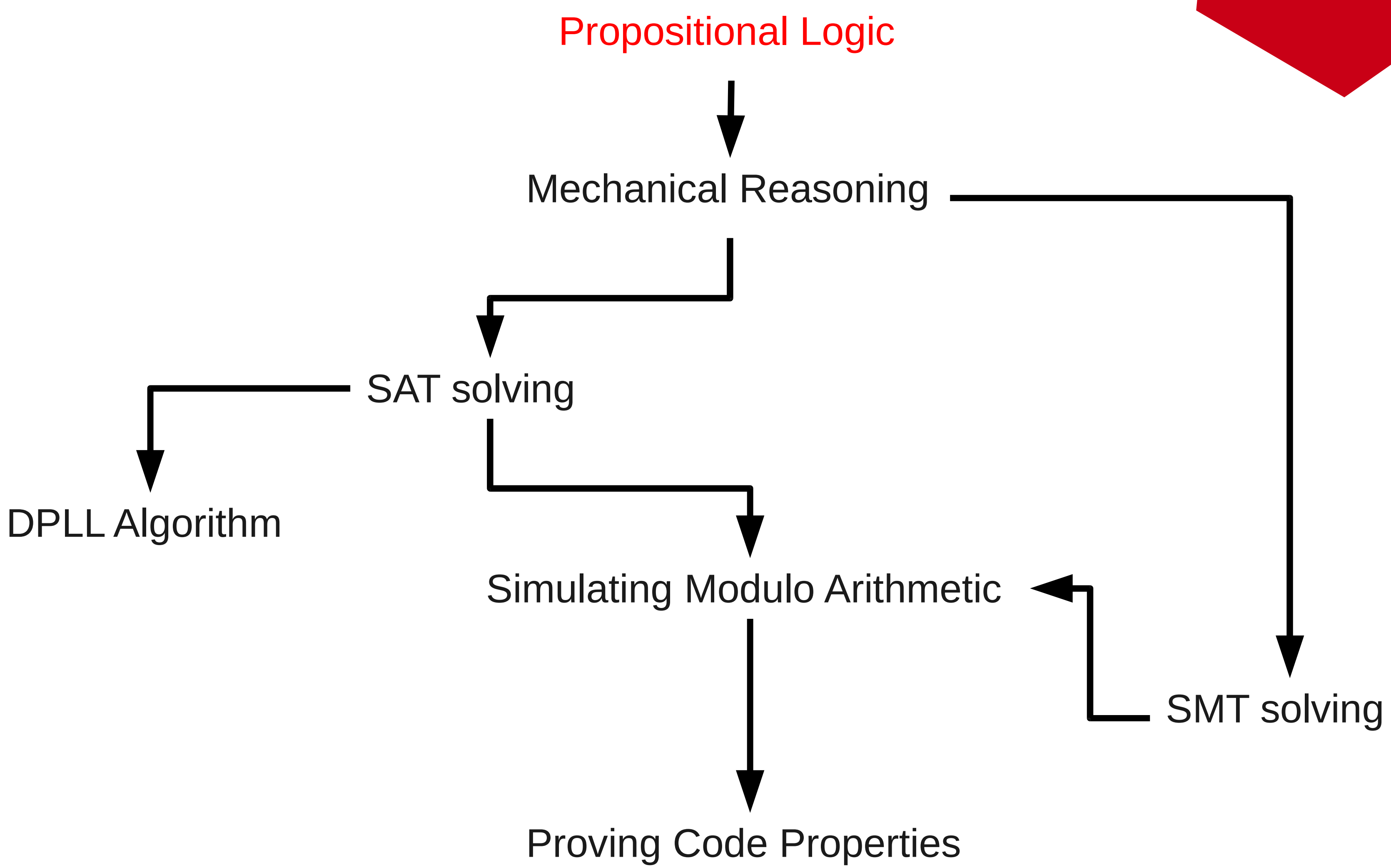
THE (IN)COMPLETE GUIDE TO CODE ANALYSIS CARPENTRY

Or how to avoid braining yourself when handed an SMT solving hammer

IMMUNITY INC.

```
void* ArrayBuffer::tryAllocate(unsigned numElements,
                               unsigned elementByteSize)
{
    void* result;
    // Do not allow 32-bit overflow of the total size
    if (numElements) {
    unsigned totalSize = numElements * elementByteSize;
    if (totalSize / numElements != elementByteSize)
        return 0;
    }
    if (WTF::tryFastCalloc(numElements,
                           elementByteSize).getValue(result))
        return result;
    return 0;
}
```

PART I: DOWN THE RABBIT HOLE



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Mechanical “Reasoning”

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Mechanical “Reasoning”

[1] This is incomplete but sufficient for our purposes. Wikipedia does a relatively good job for a lot of what we'll cover. Otherwise see http://www.unprotectedhex.com/psv/ for books.

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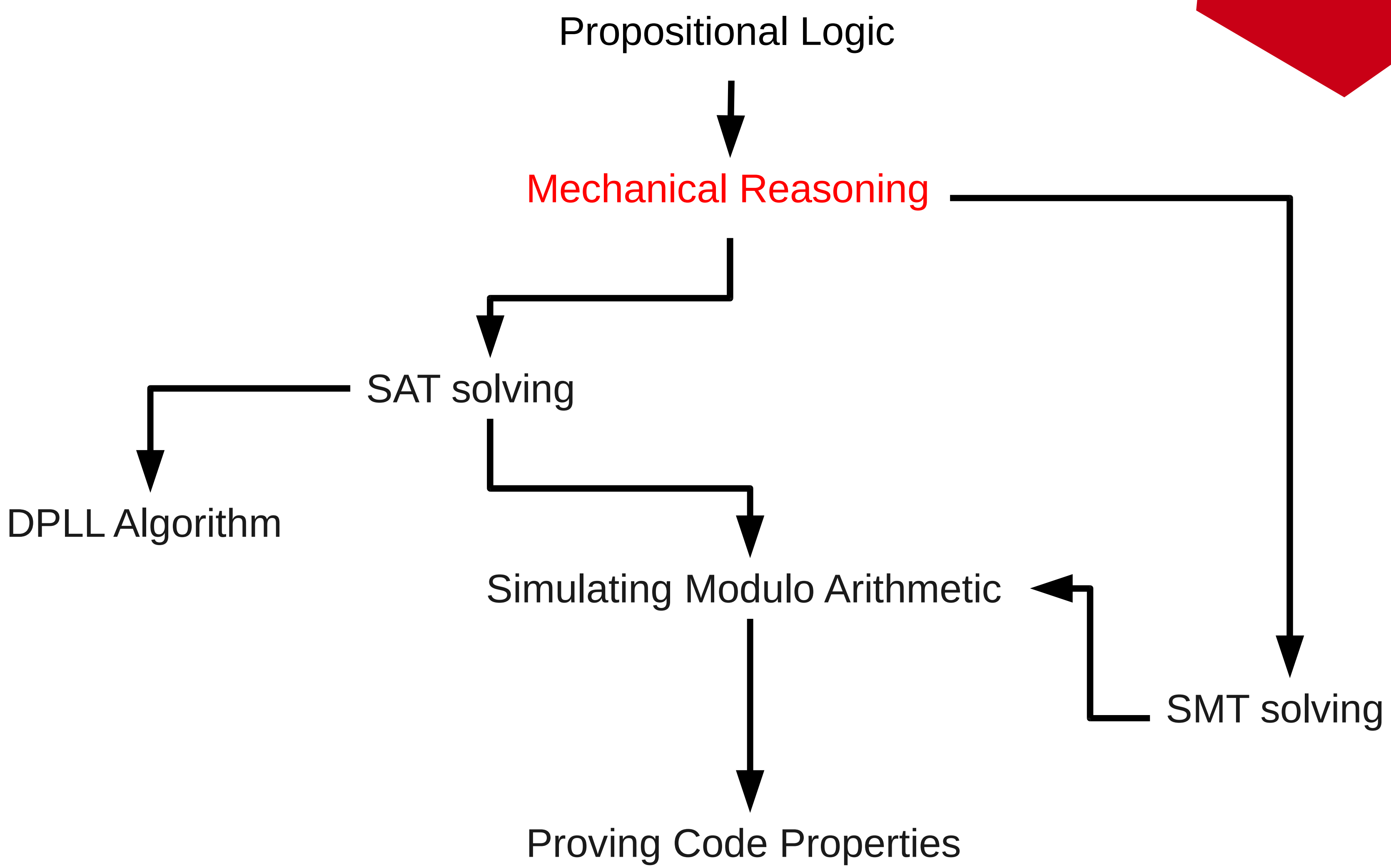

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(Truth Table)

p	~p
T	F
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Mechanical Reasoning (cont)

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X is satisfied if it reduces to T under any model

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Boolean satisfiability problem – *Find such an assignment or prove that none exists*

→ SAT solving

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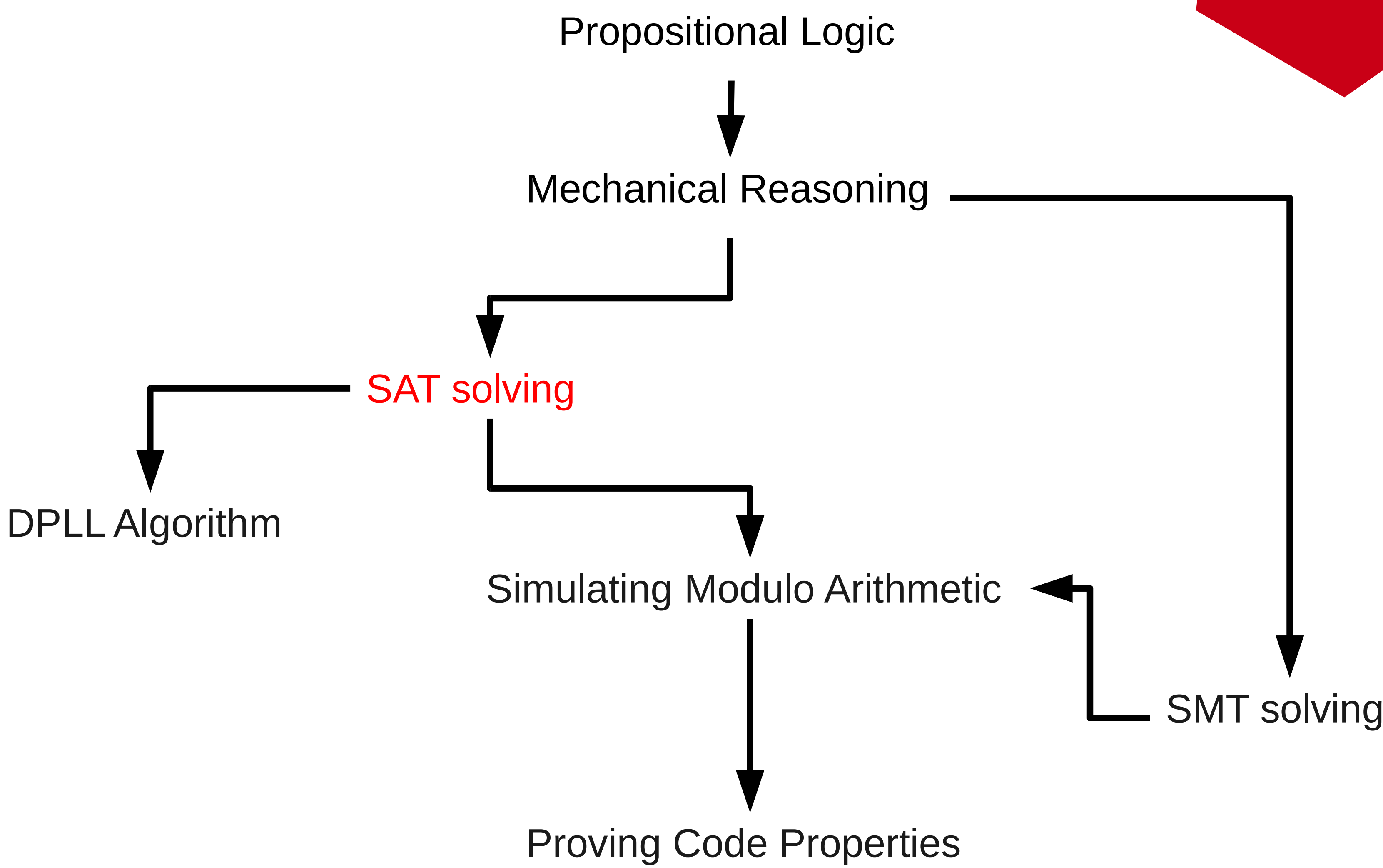

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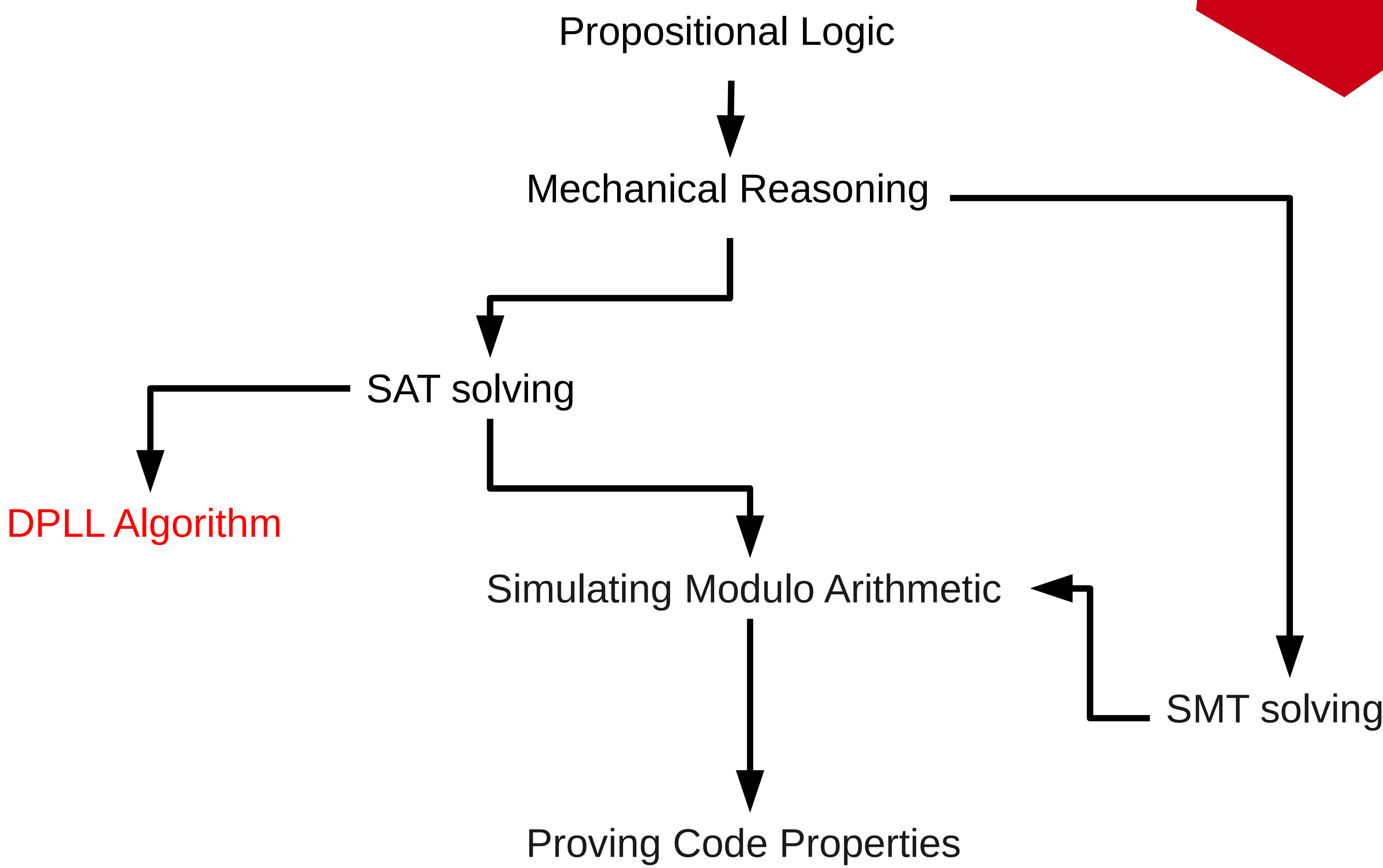

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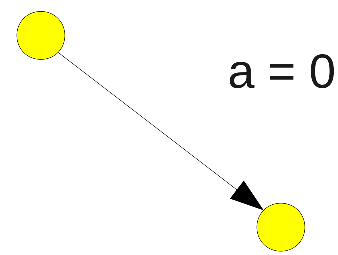

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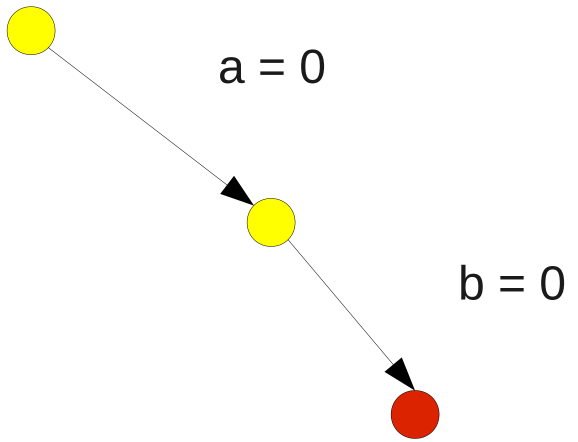

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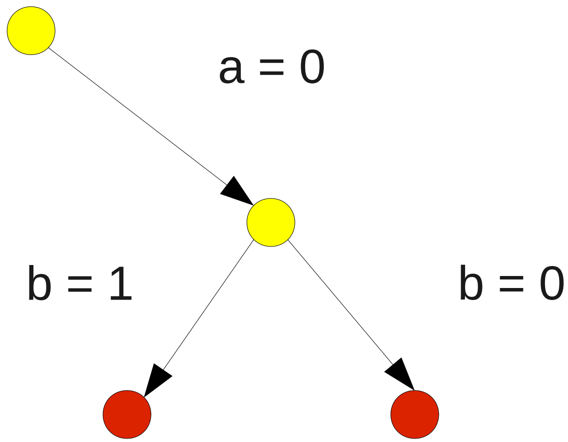

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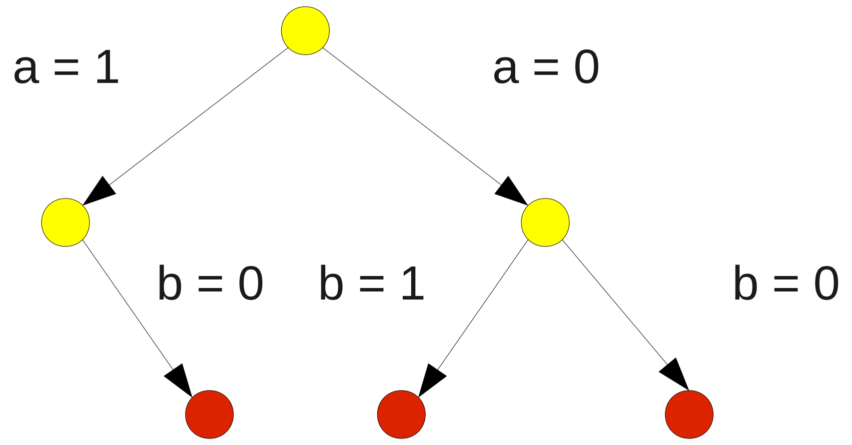

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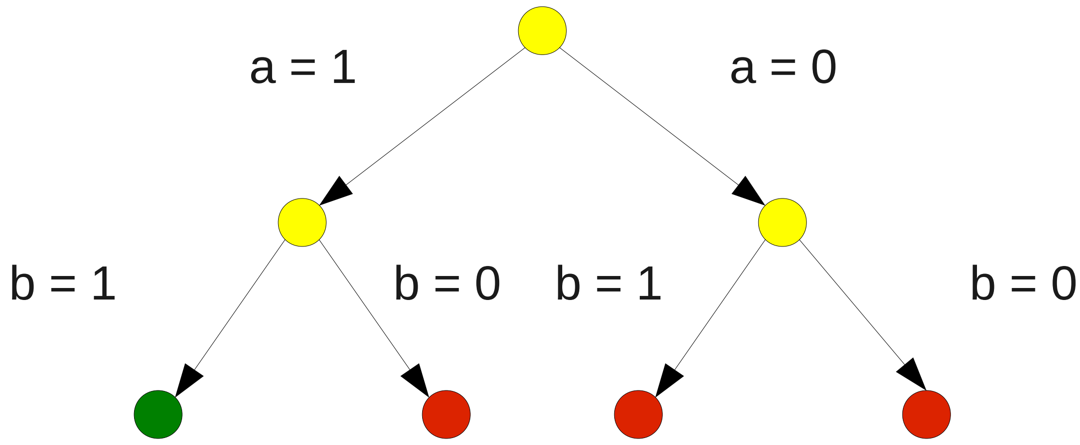

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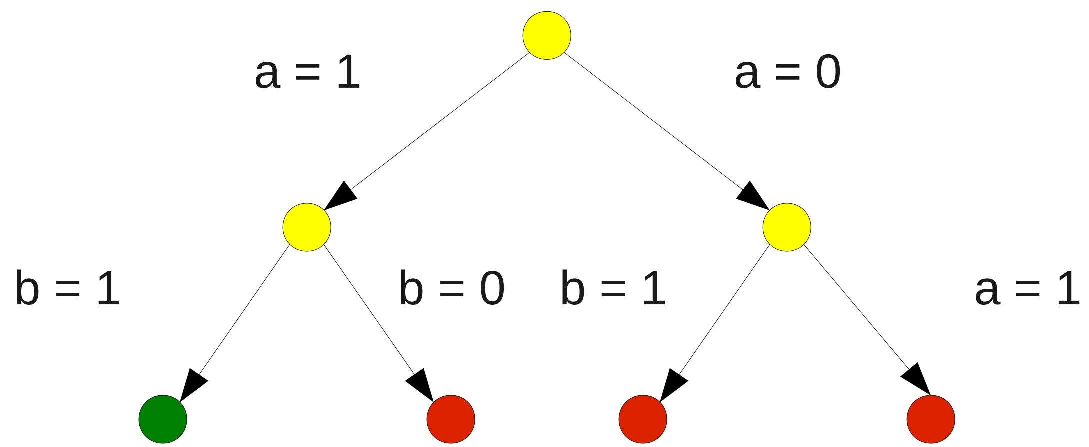

DPLL and other optimisations work by attempting to prune the tree and limit the cases we need to consider

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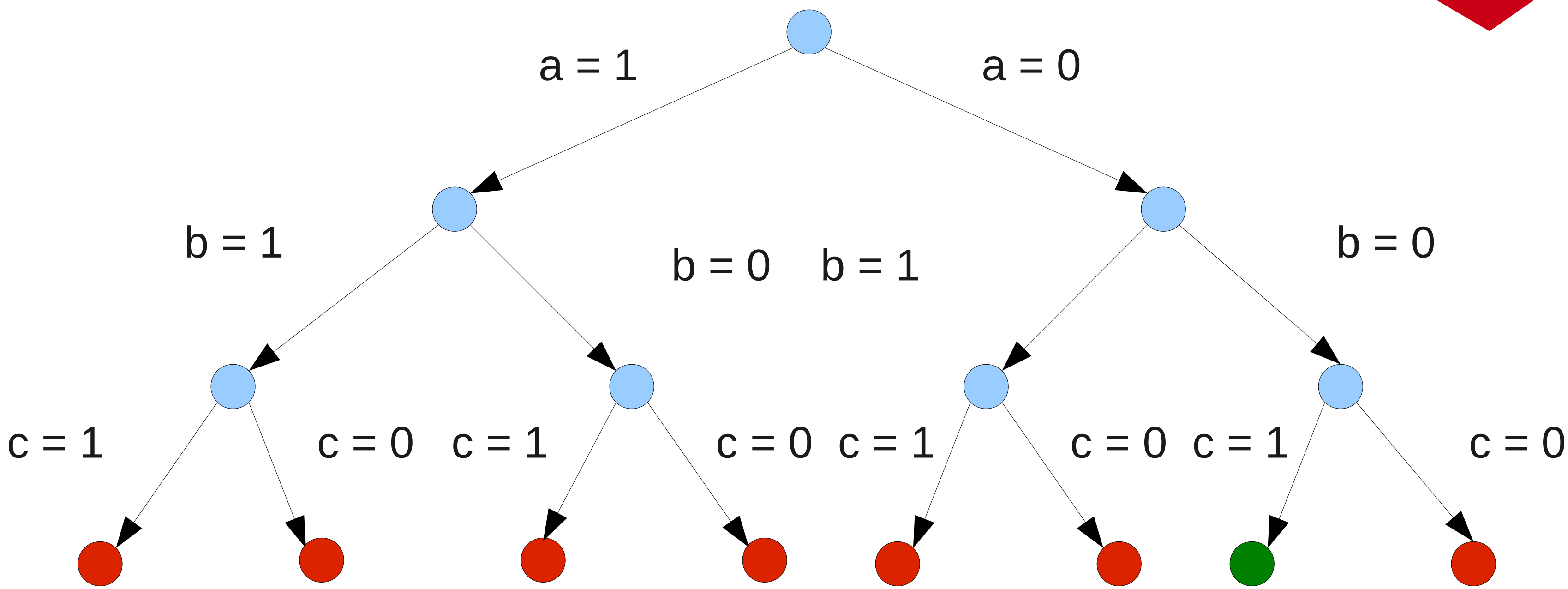

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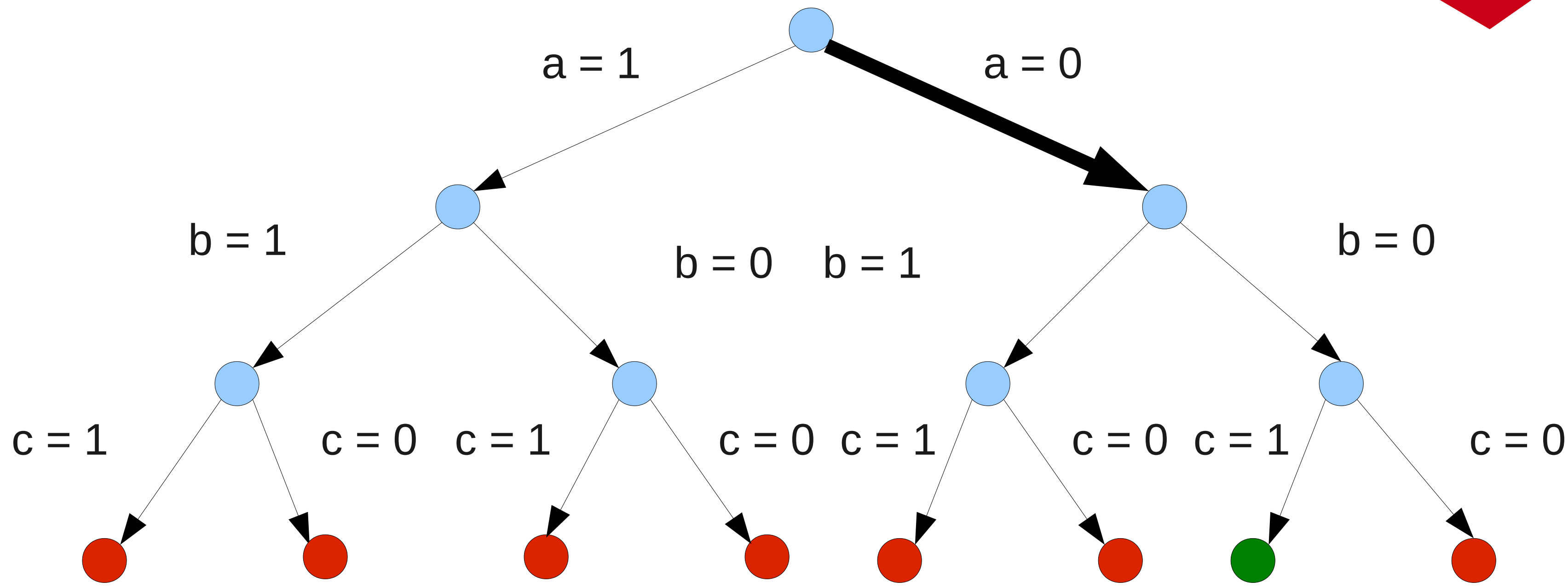

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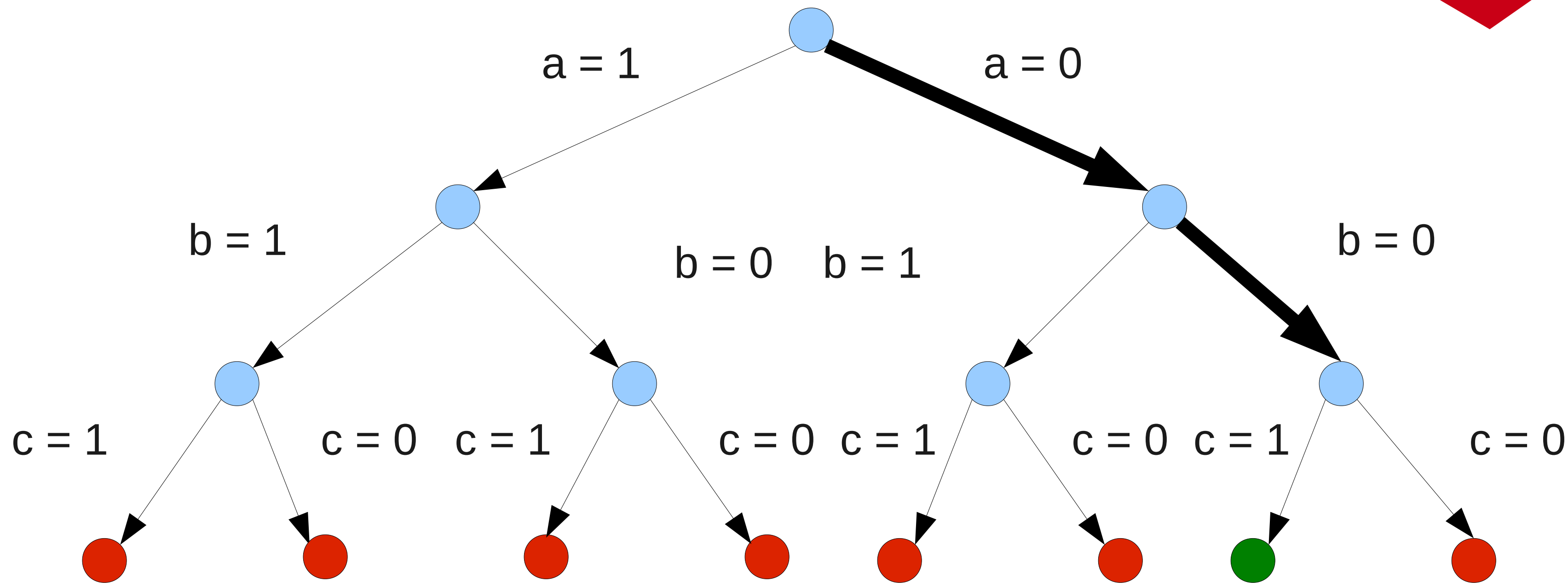

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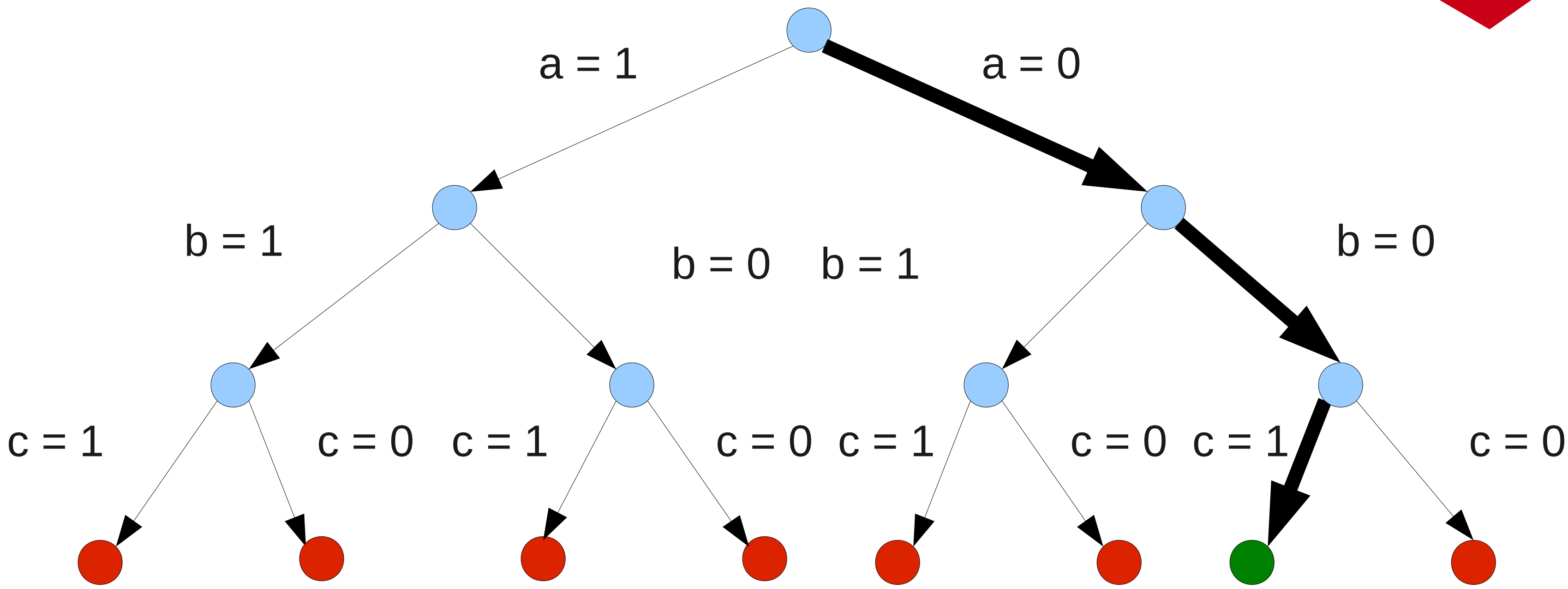

No search required in this case

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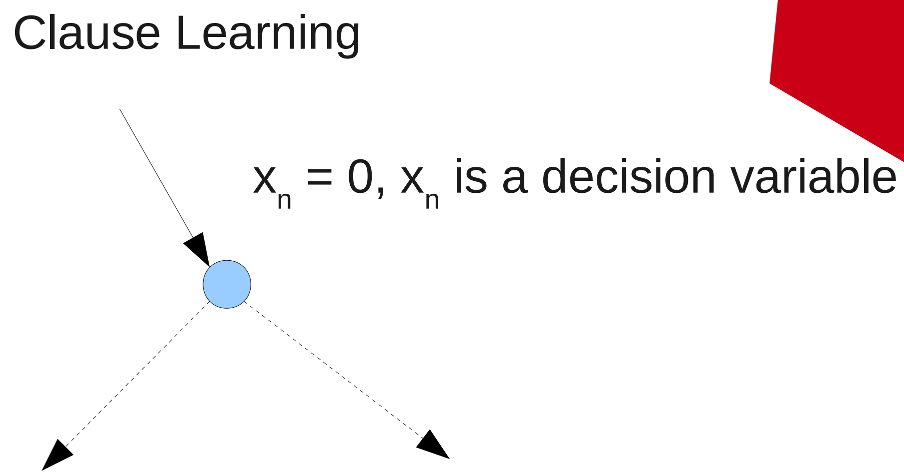

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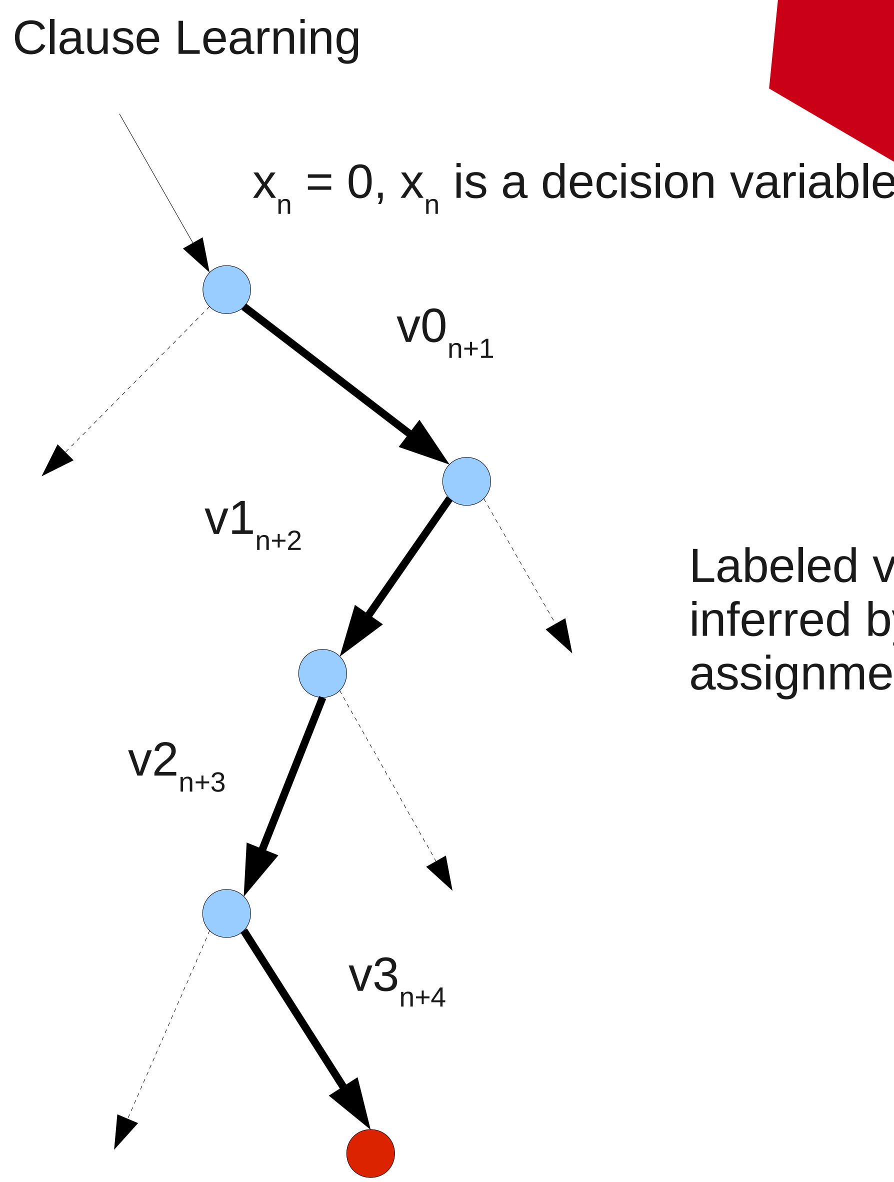

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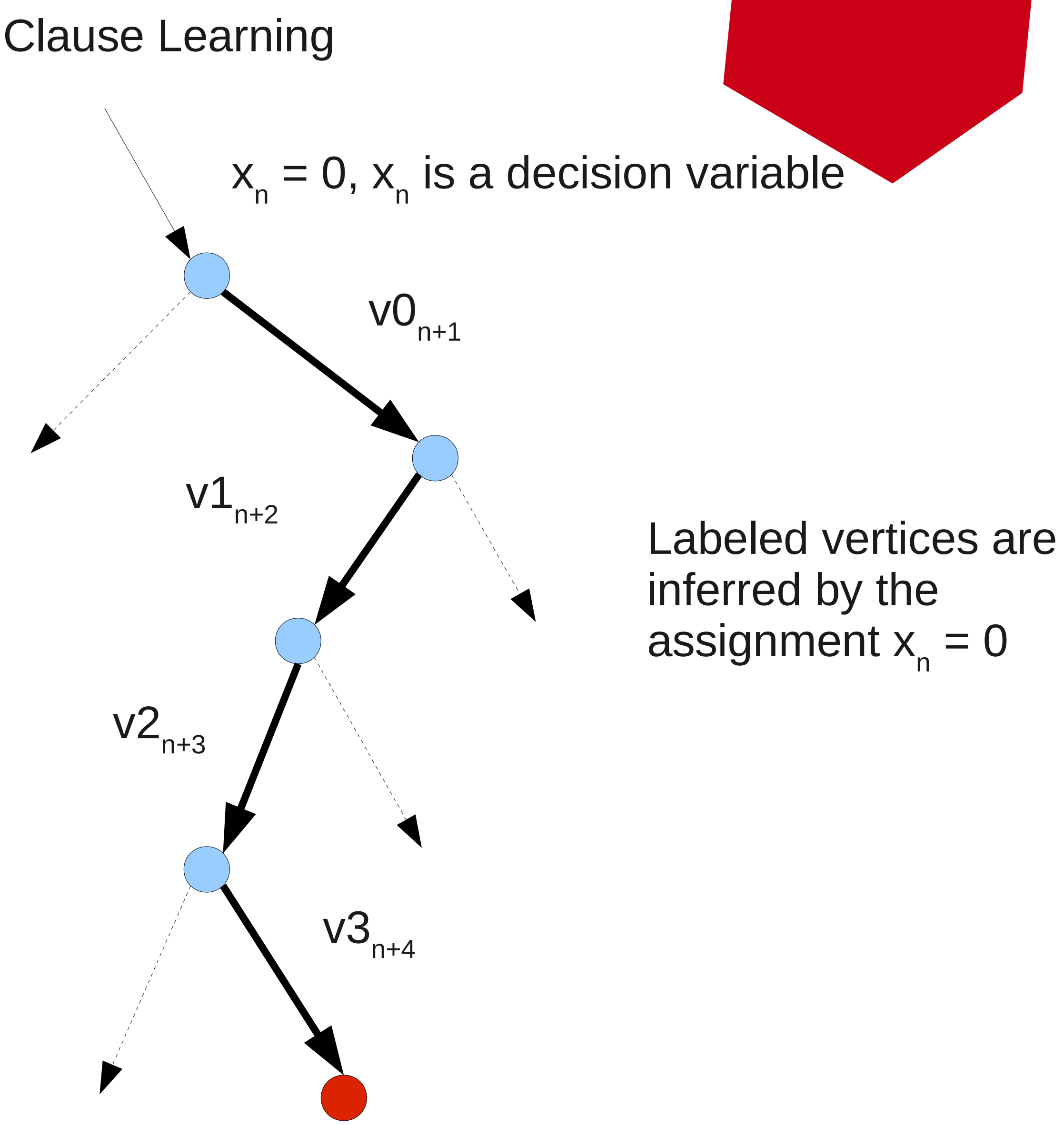
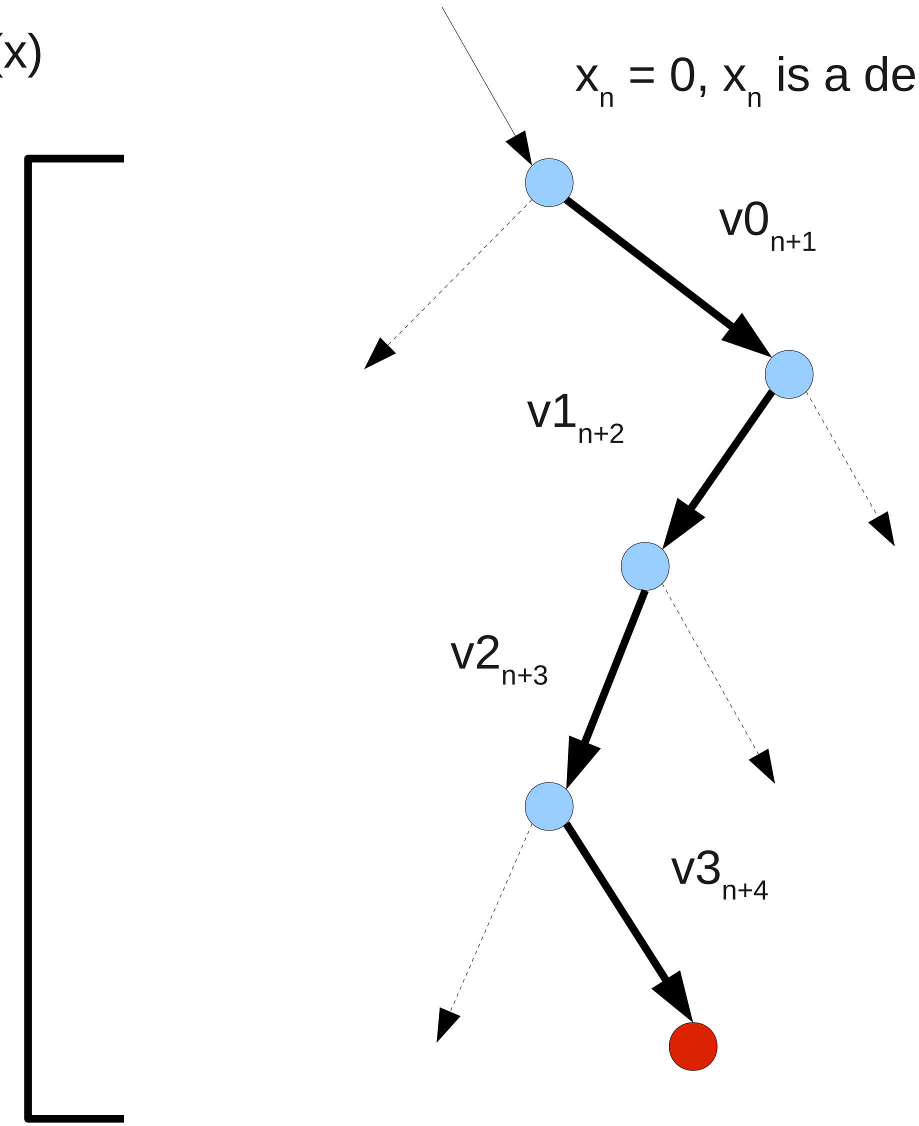


DPLL ALGORITHM (CONT)

Clause Learning

The learned clause is (x)

$x_n = 0$, x_n is a decision variable



This entire sub-tree is effectively pruned

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Restarts after a given timeout to reduce sensitivity to unfortunate branch selection

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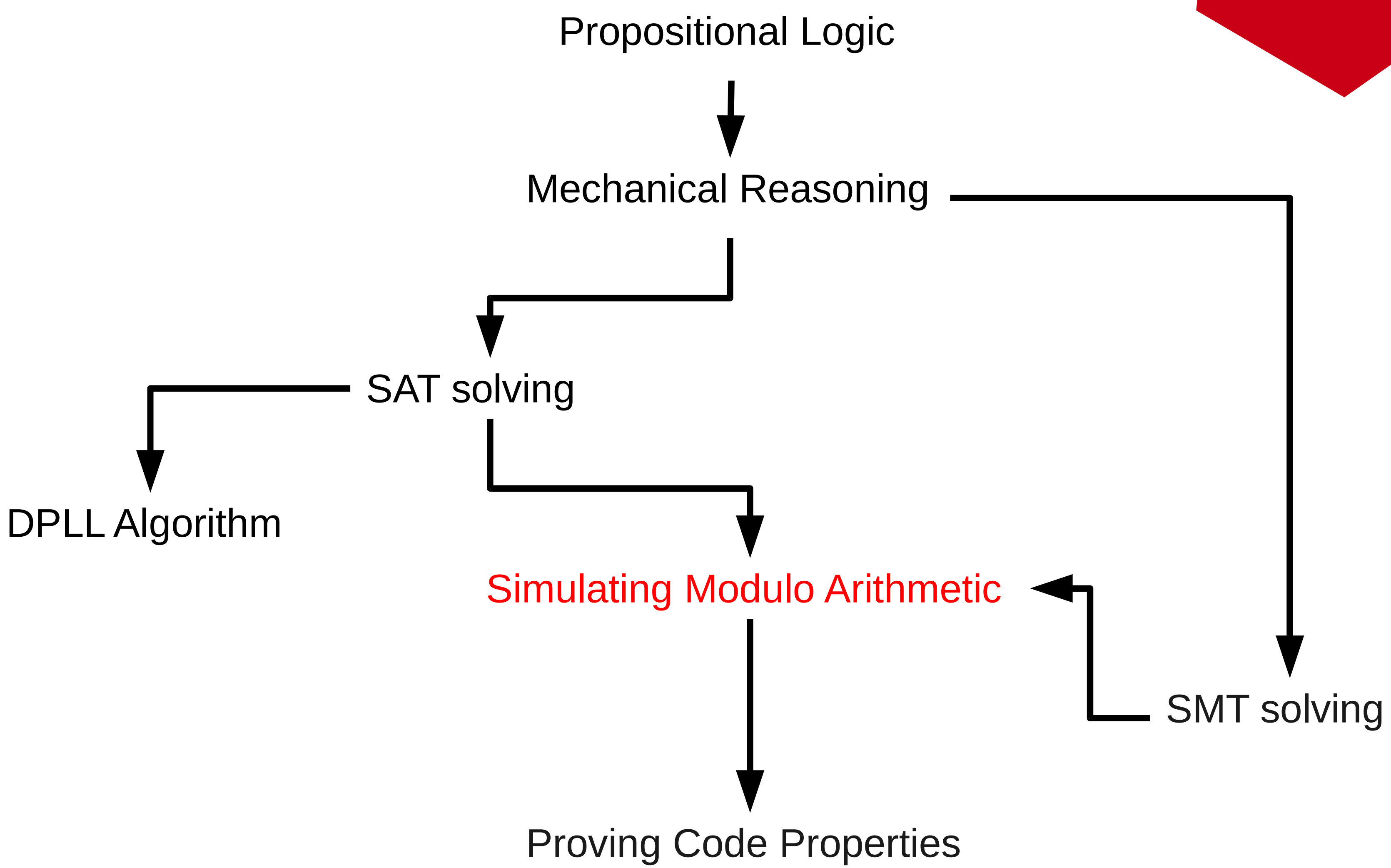

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cin_n = 0 if n == 0 or $carry_{n-1}$ otherwise

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Can be extended to bitvectors of arbitrary lengths and used to represent subtraction

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Single multiplier – 8 bits[1]

n	# Vars	# Clauses
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16	1265	4177
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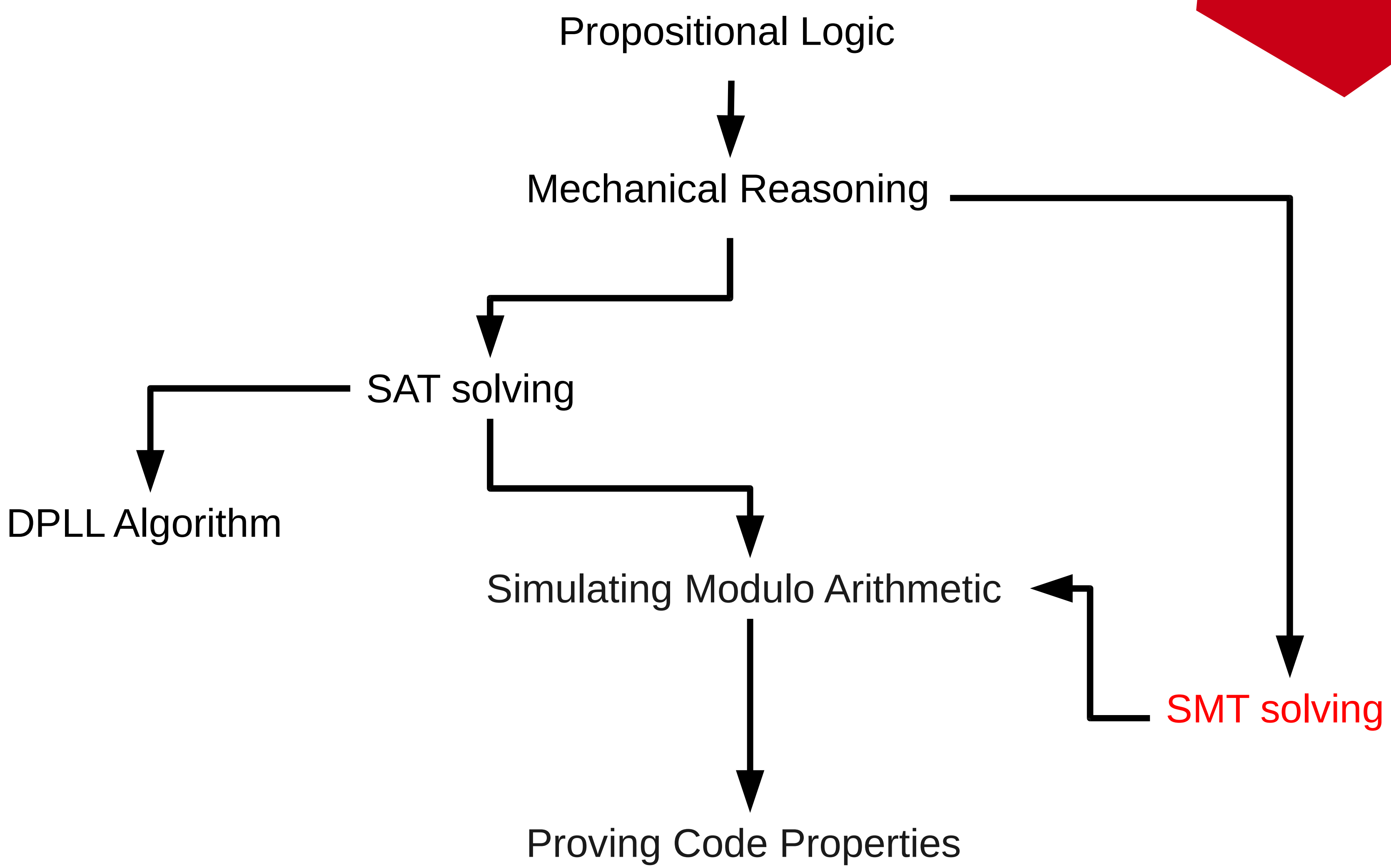

SMT SOLVERS

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$$(a < b) \wedge (b < 10) \wedge (c = a + 1) \wedge (c = 10)$$

Encode skeleton as a boolean formula $x_0 \wedge x_1 \wedge x_2 \wedge x_3$

Find a satisfying assignment $x_0 = x_1 = x_2 = x_3 = T$

Use a theory specific solver to check if this assignment is feasible $(a < b) \wedge (b < 10) \wedge (c = a + 1) \wedge (c = 10)$

[1] For sanity I've avoided a discussion of first order logic, decidability and combining theories that is relatively important. See Wikipedia or http://unprotectedhex.com/psv

SMT SOLVERS

Provide a much more intuitive encoding of programming language semantics

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Theories for arrays, lists, sets etc

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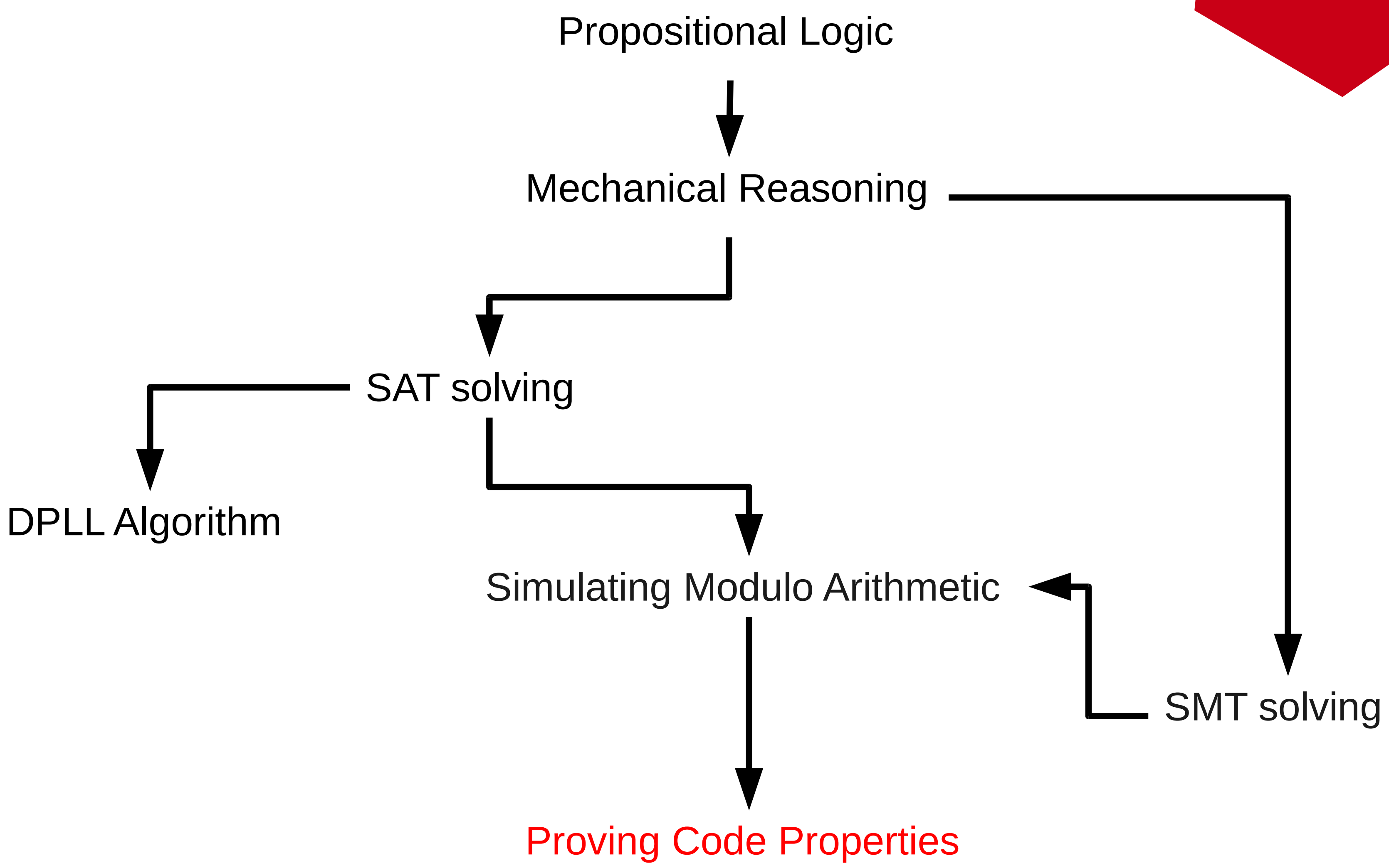
SMT-LIB specification describes a number of base theories and provides functions over them

bvadd, bvmul, bvand, bvor, bvult, bvugt etc

PART 1: DOWN THE RABBIT HOLE



WebKit Code

```
void* ArrayBuffer::tryAllocate(unsigned numElements,
                unsigned elementByteSize)
{
    void* result;
    // Do not allow 32-bit overflow of the total size
    if (numElements) {
    unsigned totalSize = numElements * elementByteSize;
    if (totalSize / numElements != elementByteSize)
        return 0;
    }
    if (WTF::tryFastCalloc(numElements,
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        return result;
    return 0;
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SMT-LIB model

```
(benchmark uint_ovf
:status unknown
:logic QF_BV

:extrafuns ((totalSize BitVec[32])(numElements BitVec[32])
        (elSize BitVec[32]))

; elSize != 0
; This assumption isn't actually accounted for in the code
:assumption (bvugt elSize bv0[32])
; if (numElements) {
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; unsigned totalSize = numElements * elementByteSize;
:assumption (= totalSize (bvmul numElements elSize))

; totalSize / numElements != elementByteSize
:assumption (= elSize (bvudiv totalSize numElements))

; Our requirement totalSize < numElements
:formula (bvult totalSize numElements)
)
```

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:formula (bvult totalSize numElements)
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```

```
[sean@sean-laptop bin]$ time ./yices -f webkit.smt
unsat

real    0m0.220s
user    0m0.212s
sys     0m0.005s
```

Part II: One Hammer, Many Nails

ROP

↓

Path Filtering

↓

Finding variable bounds

↓

Finding integer overflows

↓

Loops and solvers

↓

Performance/Scaling

PART II: ONE HAMMER, MANY NAILS

ROP

↓

Path Filtering

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Finding variable bounds

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↓

Loops and solvers

↓

Performance/Scaling

WHICH OF THESE EXPRESS EAX = 0

```
MOV EAX,DWORD PTR SS:[EBP-4]
POP EDI
POP ESI
POP EBX
LEAVE
RETN 4
```

```
MOV EAX,ESI
POP ESI
POP EBP
RETN 8
```

```
XOR EAX,EAX
INC EAX
POP EDI
POP ESI
POP EBX
LEAVE
RETN 8
```

```
ADC BYTE PTR DS:[ECX+C5E82404],CL
OR AL,BYTE PTR DS:[EAX]
ADD BYTE PTR DS:[EBX+658D14EC],AL
CLC
POP EBX
POP ESI
POP EBP
RETN 10
```

```
XOR EDI,EDI
MOV EAX,EDI
POP EDI
LEAVE
RETN 4
```

```
XOR EAX,EAX
POP ESI
LEAVE
RETN 4
```

```
MOV ESI,DWORD PTR SS:[EBP-8]
MOV EDI,DWORD PTR SS:[EBP-4]
SUB ESP,4
MOV ESP,EBP
POP EBP
RETN 10
```

```
SBB EAX,EAX
AND EAX,7FF6FD00
ADD EAX,80090300
POP EBP
RETN 8
```

```
ADD EAX,90302B8
ADD BYTE PTR SS:[EBP+8B0B7CC0],4D
ADC AL,8B
PUSH EBP
CLD
MOV DWORD PTR DS:[ECX+4],EDX
MOV DWORD PTR DS:[ECX],ESI
POP ESI
LEAVE
RETN 10
```

```
MOV AL,BYTE PTR SS:[EBP+B]
POP EDI
POP ESI
POP EBX
LEAVE
RETN 14
```

REASONING ABOUT X86 USING SMT SOLVERS

1) Convert x86 to SMT representation *F*

(We've seen it's possible to model code as formulae so we just need to automate that)

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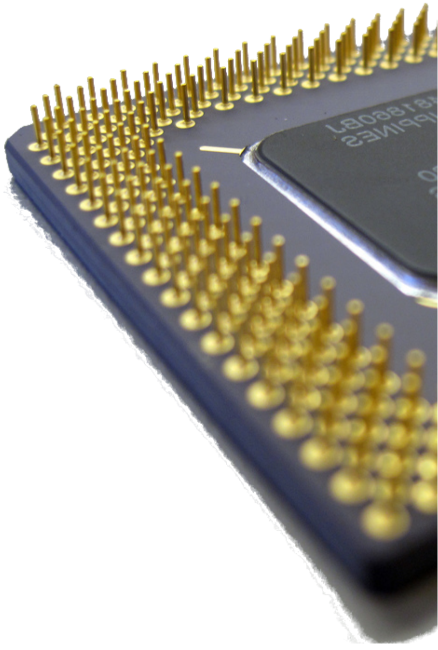

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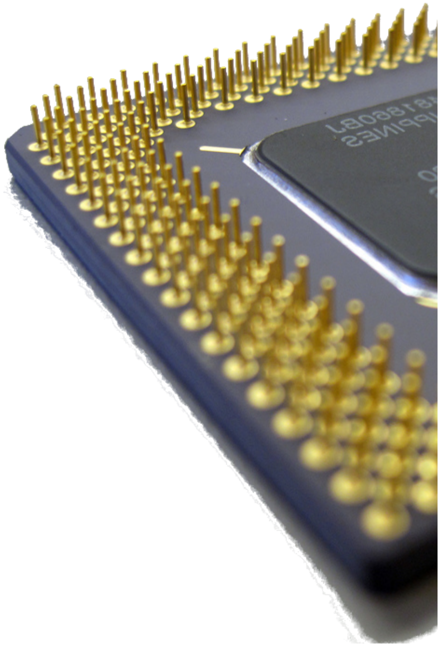

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Equivalence vs Implication
(Side effects)

EAX == 0

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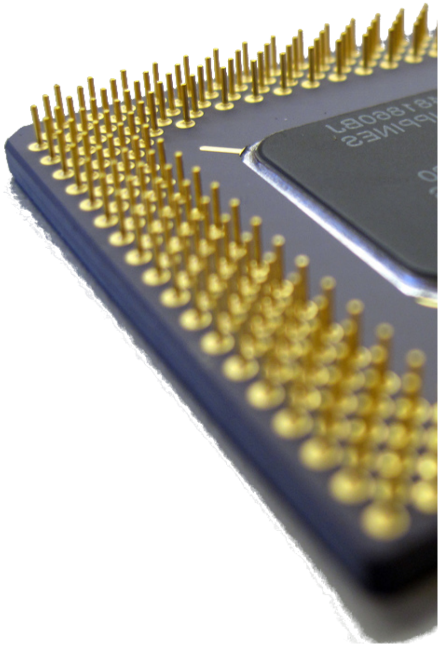
POP EDI
LEAVE
RETN 4
```



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EAX == 0

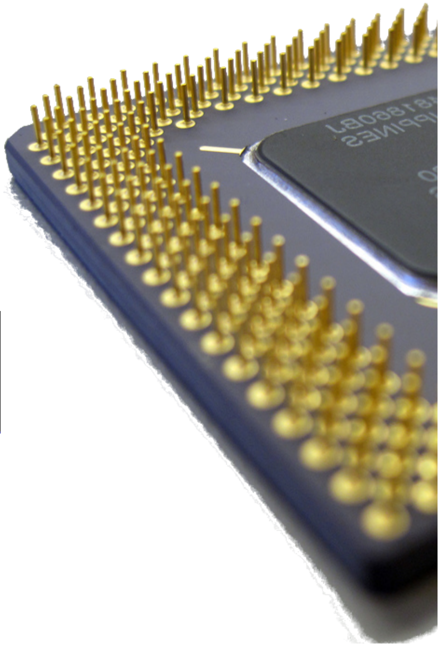
```
XOR EDI,EDI
MOV EAX,EDI
POP EDI
LEAVE
RETN 4
```

Validity versus Satisfiability
(Context sensitive gadgets)

```
XOR EAX,EAX
POP ESI
LEAVE
RETN 4
```

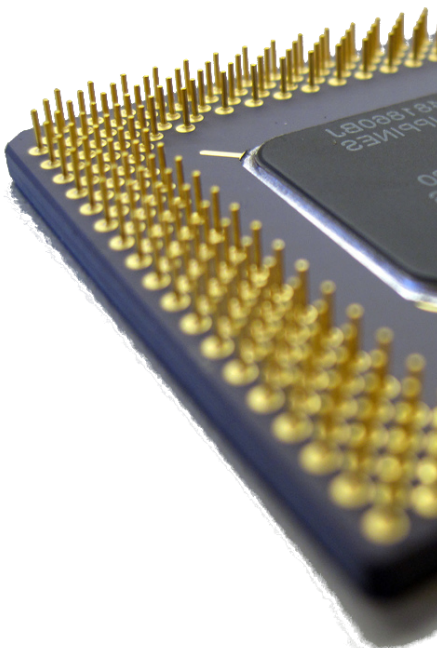
vs

```
MOV EAX,ESI
POP ESI
POP EBP
RETN 8
```



REASONING ABOUT X86 USING SMT SOLVERS

```
XOR EAX,EAX
INC EAX
POP EDI
POP ESI
POP EBX
LEAVE
RETN 8
```



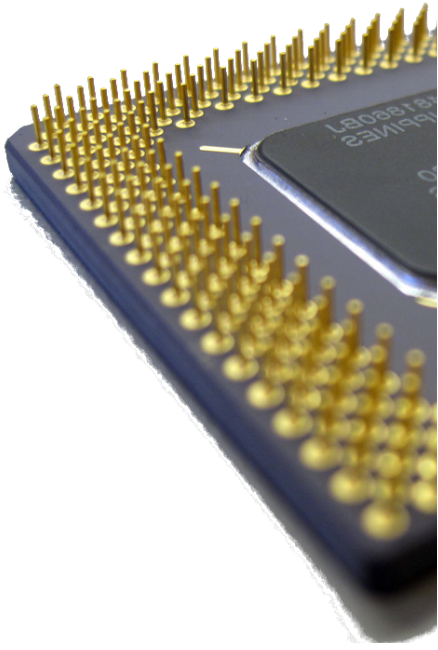
REASONING ABOUT X86 USING SMT SOLVERS

```
XOR EAX,EAX
INC EAX
POP EDI
POP ESI
POP EBX
LEAVE
RETN 8
```

```python
def analyzeXOR(self, op):
    dst = self.buildState(op.operand[0]);
    src = self.buildState(op.operand[1]);
    (res,dstval,srcval)=self.solveArithmetic(self.state.solver.xorExpr,dst,src)
    self.updateFlags("LOGIC", res, dstval, srcval)

def analyzeINC(self, op):
    cf = self.state.flags['_CF']
    op.operand = (op.operand[0], op.constantOperand(1), op.emptyOperand())
    self.analyzeADD(op)
    self.state.flags['_CF'] = cf


def analyzeRETN(self, op):
    self.state.EIP = self.getMemoryStateFromSolverState(self.state.regs['ESP'], 32)
    self.state.RETNoffset = self.state.solver.constExpr(op.op1Constant())
    self.state.regs['ESP'] = self.state.solver.addExpr(self.state.regs['ESP'],
                                 self.state.solver.addExpr(
                                     self.state.solver.constExpr(4),
                                     self.state.RETNoffset))
```



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    self.analyzeADD(op)
    self.state.flags['_CF'] = cf


def analyzeRETN(self, op):
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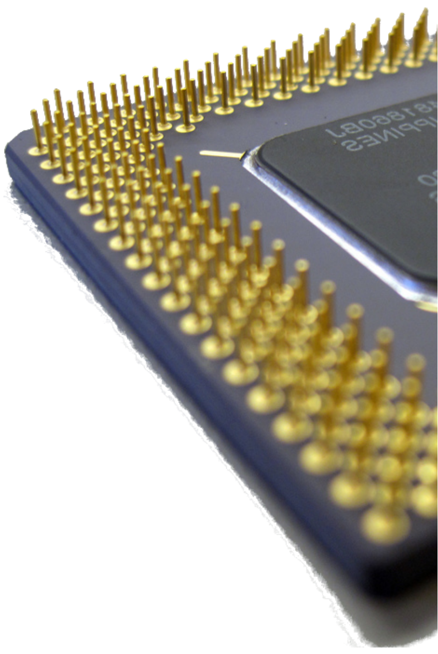
    self.state.RETNoffset = self.state.solver.constExpr(op.op1Constant())
    self.state.regs['ESP'] = self.state.solver.addExpr(self.state.regs['ESP'],
                                    self.state.solver.addExpr(
                                        self.state.solver.constExpr(4),
                                        self.state.RETNoffset))
```

```
def xorExpr(self, exp1, exp2):
    return self.CVC.vc_bvXorExpr(self.vc, exp1, exp2) | self.get_error()

def negExpr(self, exp):
    return self.CVC.vc_bvUMinusExpr(self.vc, exp) | self.get_error()

def addExpr(self, exp1, exp2, bits=None):
    if not bits: bits=self.getBitSizeFromExpr(exp1)
    return self.CVC.vc_bvPlusExpr(self.vc, bits, exp1, exp2) | self.get_error()

def subExpr(self, exp1, exp2, bits=None):
    if not bits: bits=self.getBitSizeFromExpr(exp1)
    return self.CVC.vc_bvMinusExpr(self.vc, bits, exp1, exp2) | self.get_error()
```



find_gadget.py # Finding gadgets with specific semantics

Get candidate gadgets

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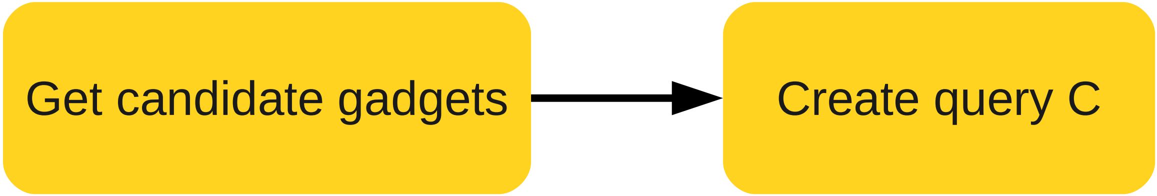
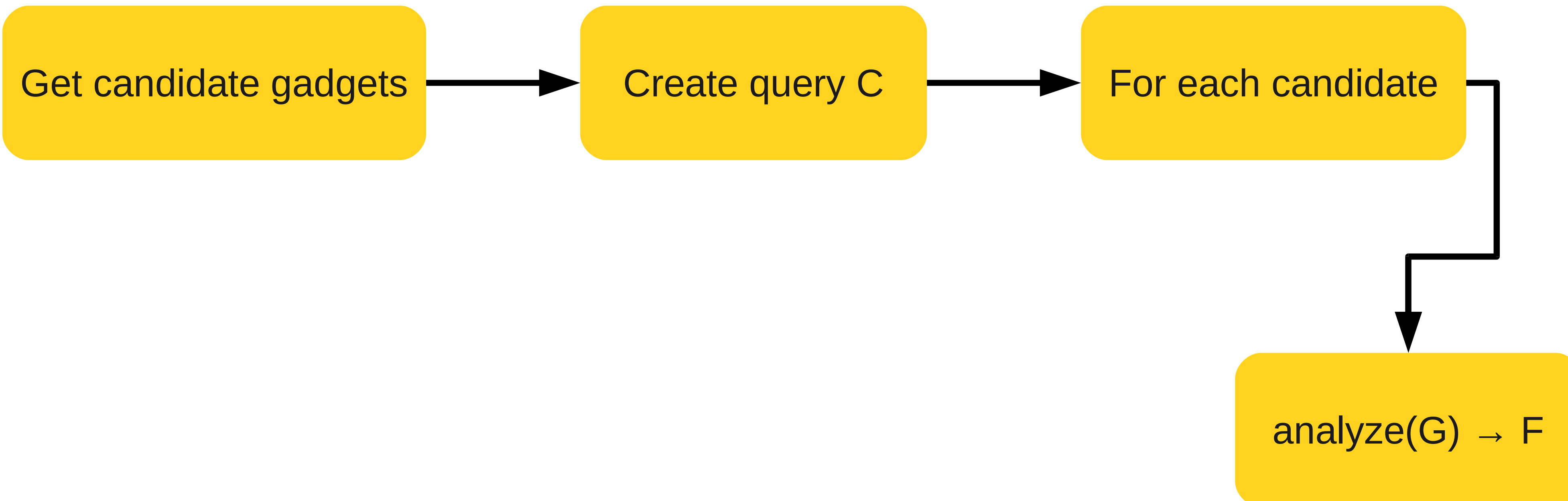
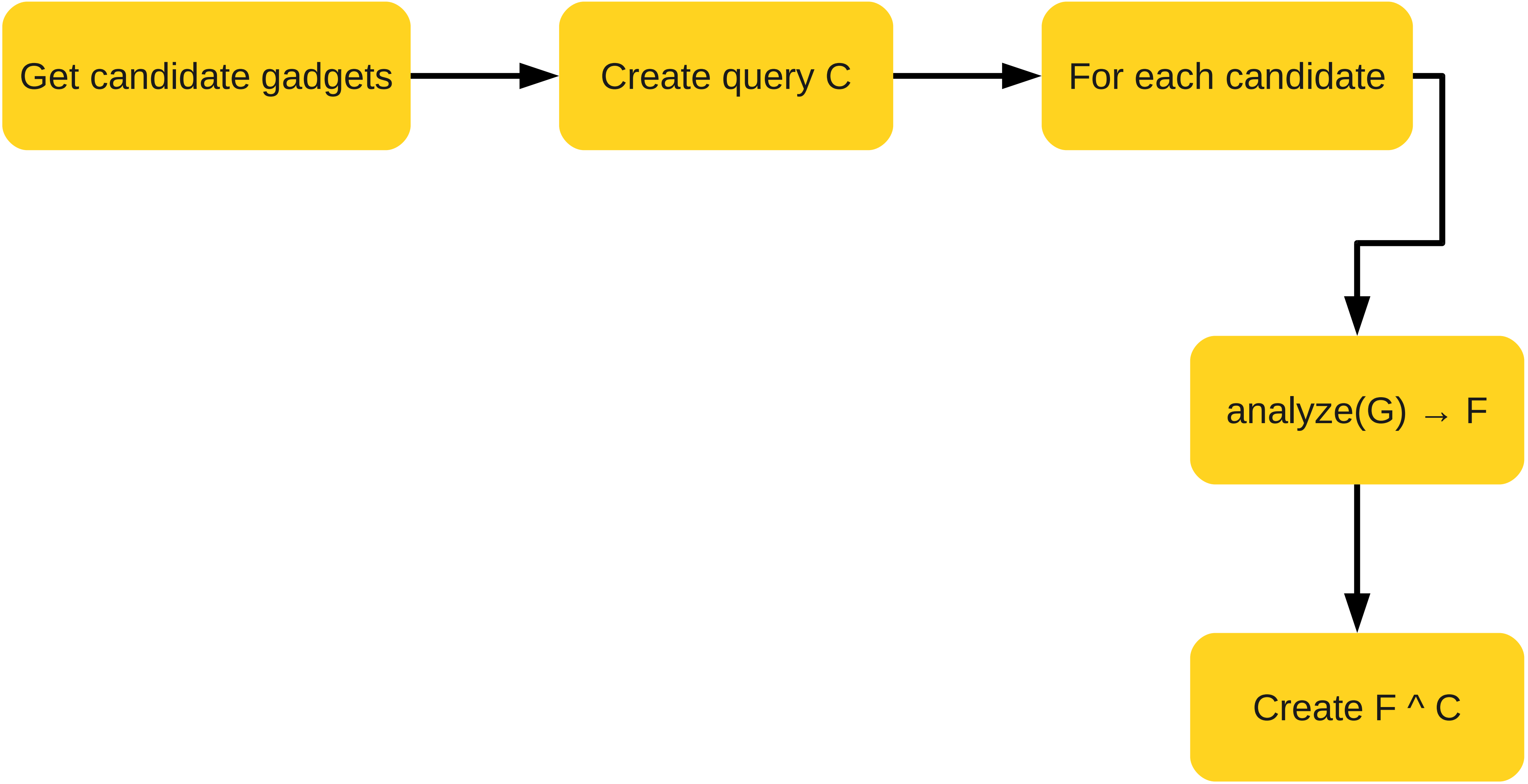


find_gadget.py # Finding gadgets with specific semantics



FIND_GADGET.PY # FINDING GADGETS WITH SPECIFIC SEMANTICS



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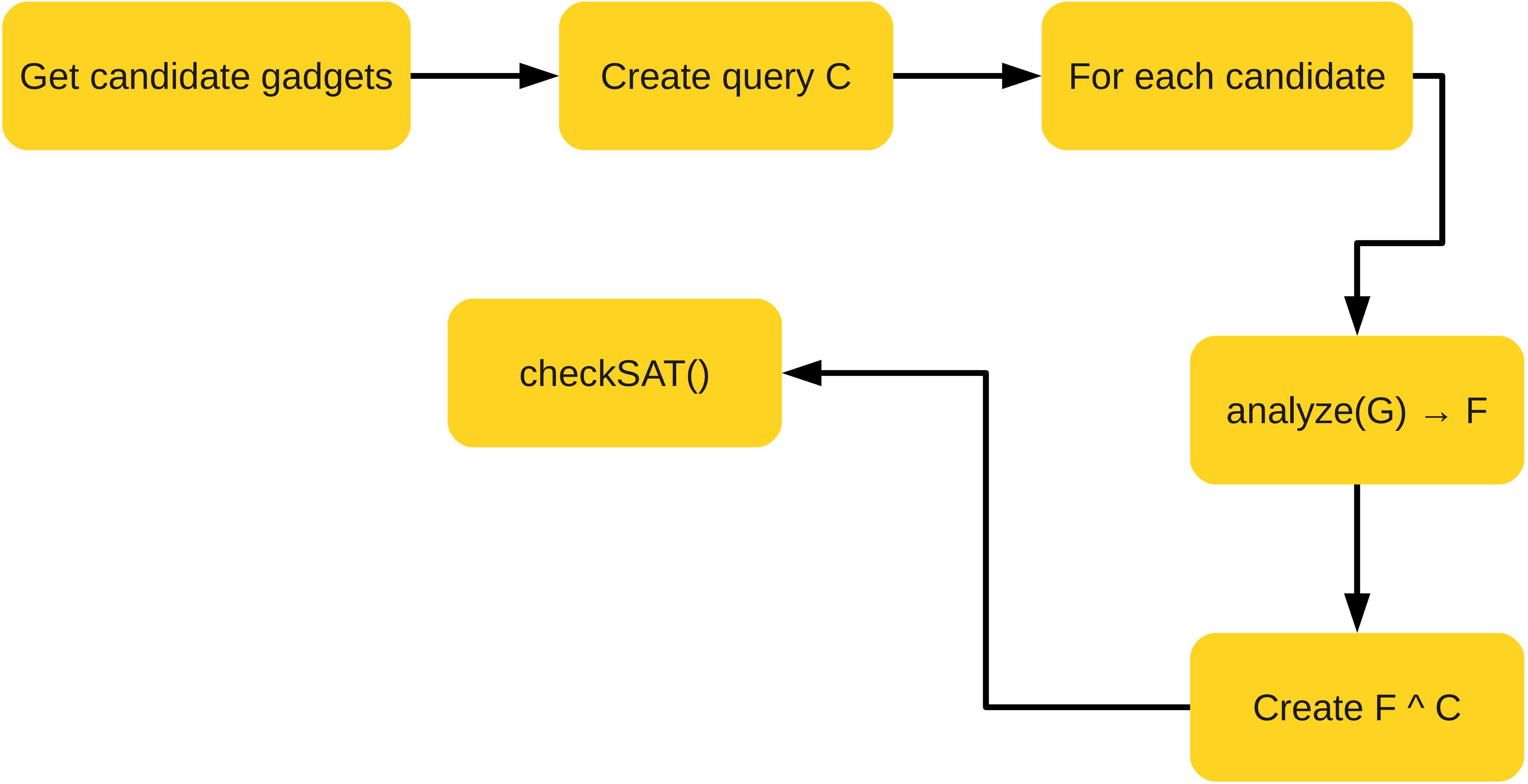

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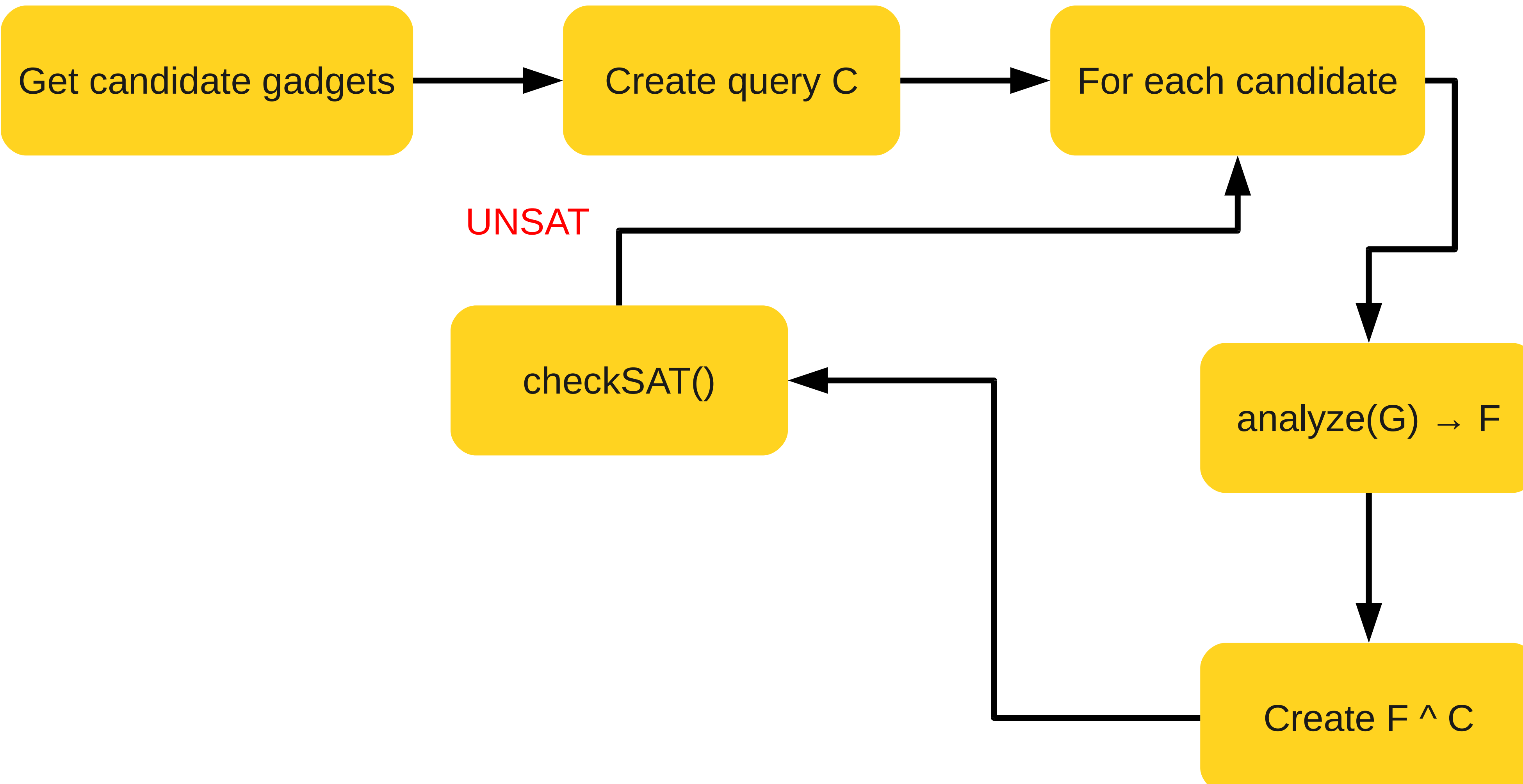

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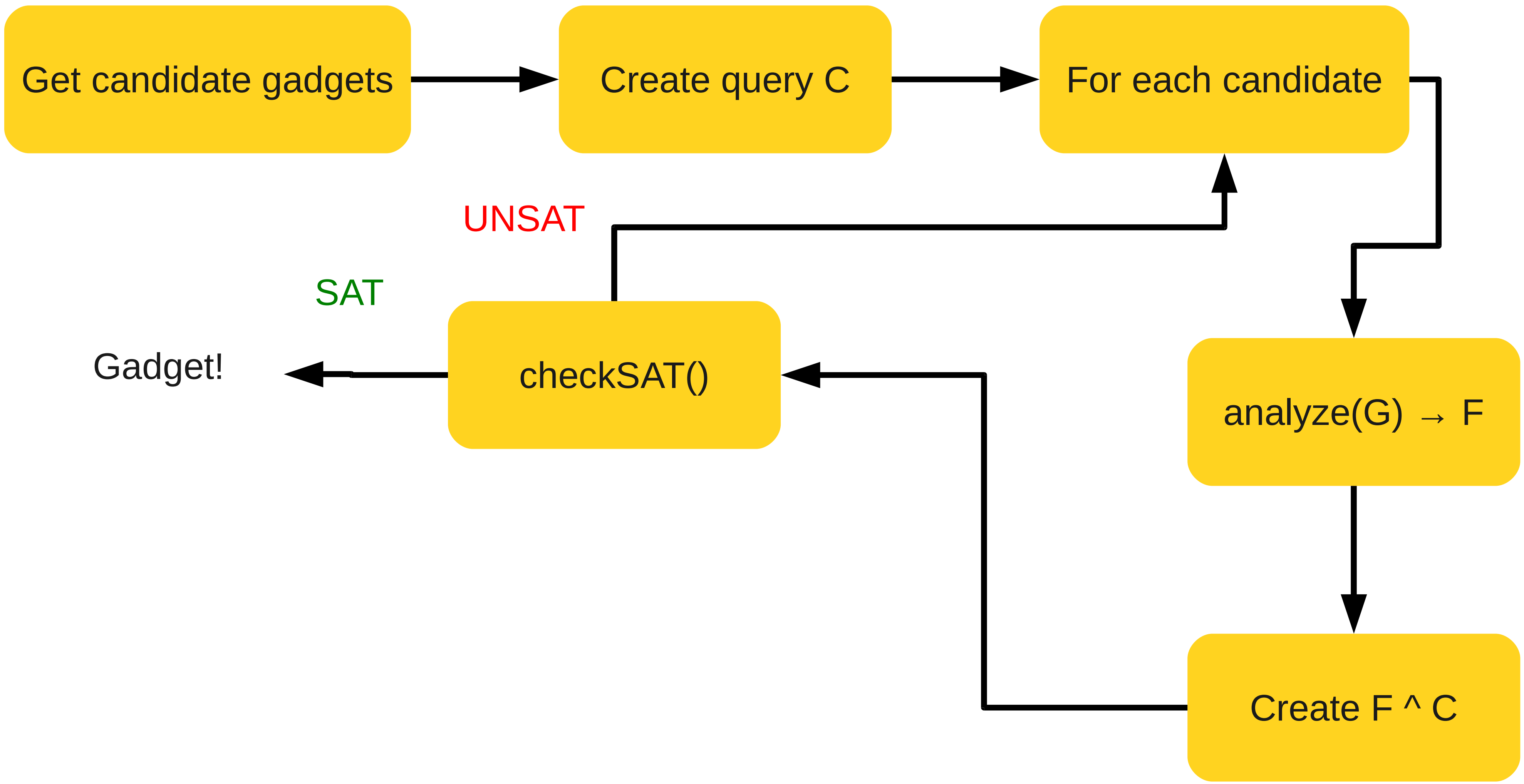

find_gadget.py # finding gadgets with specific semantics

DEMO

INFRASTRUCTURE

SequenceAnalyzer – Models x86 as operations over a set of SMT primitives

Solver – Ctypes interface to the CVC3 SMT solver API. Supports a variety of theories including quantifier free, bit-vector arithmetic, linear arithmetic etc.

Part II: One Hammer, Many Nails

ROP

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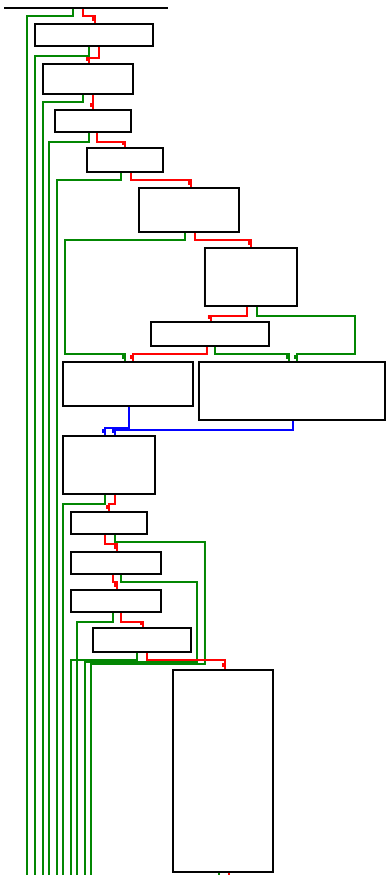
Performance/Scaling

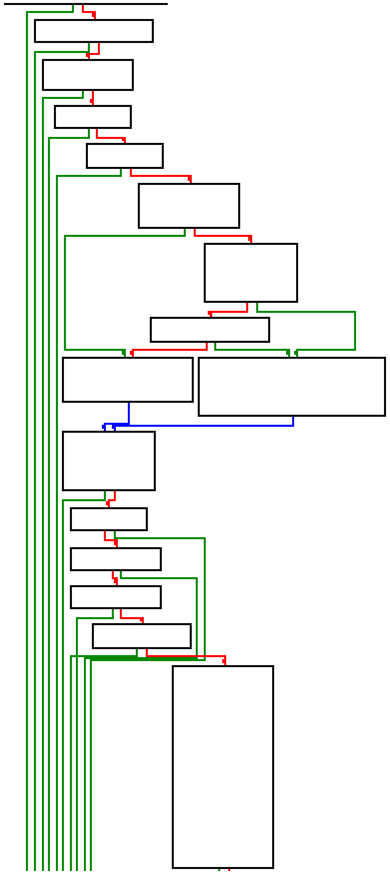
PATHOGEN.PY # FILTERING INVALID PATHS



PATHOGEN.PY # FILTERING INVALID PATHS

A problem for both manual analysis and automated tools

What paths in the CFG are actually possible given the constraints? Given a certain configuration of registers/memory?



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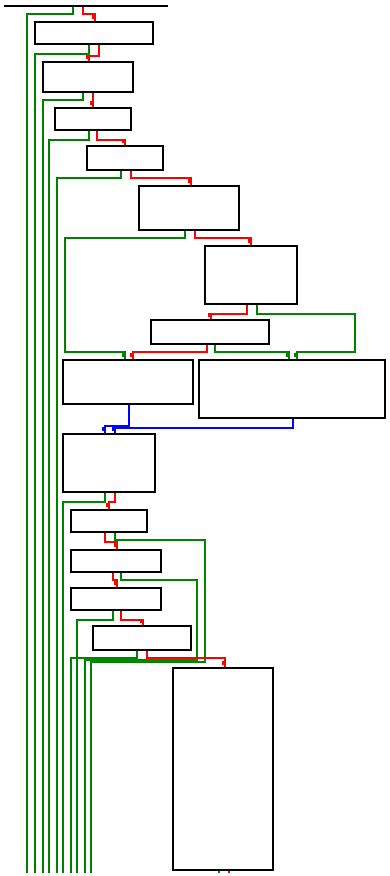

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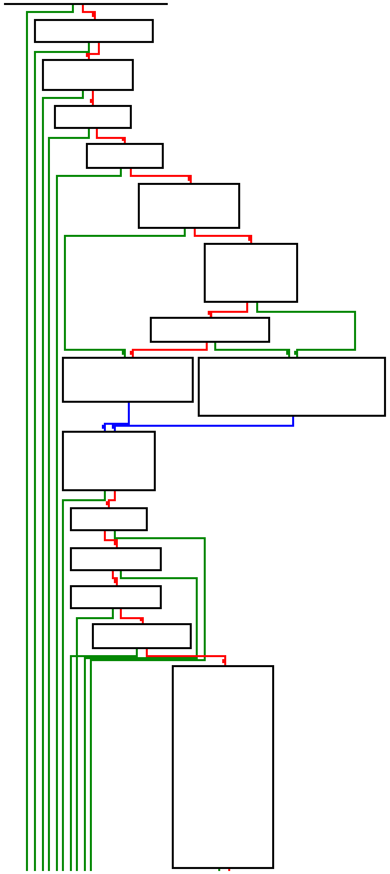

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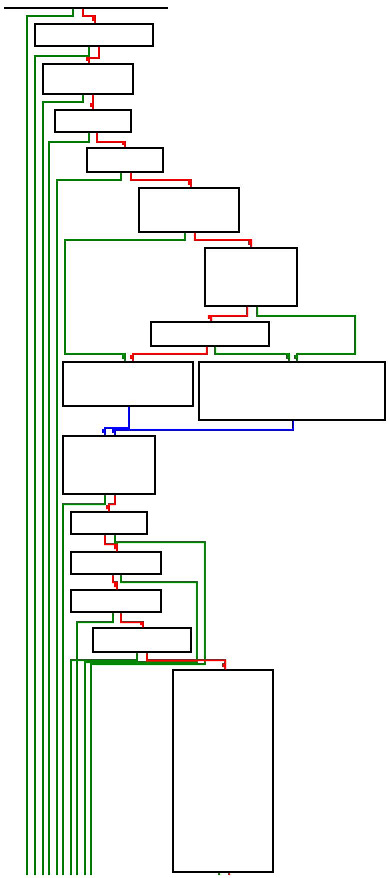

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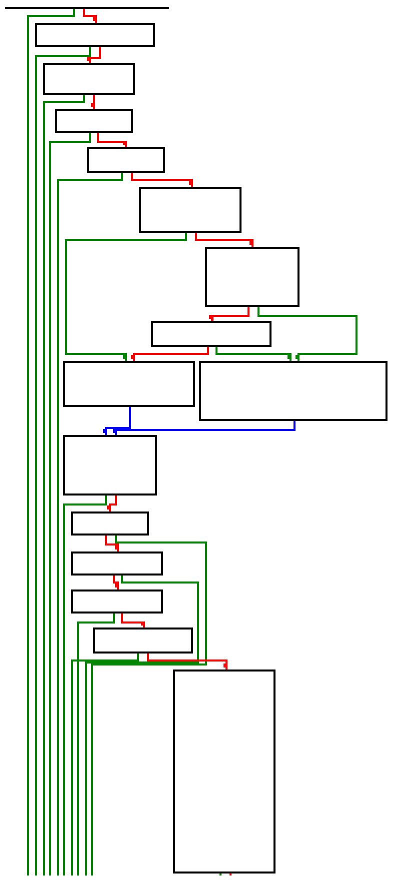

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3) Discard any paths that return UNSAT

PATHOGEN.PY # FILTERING INVALID PATHS

Path iterator

Checks conditions as it walks the path

```
# Use the path generator to dump all possible paths
pg = PathGenerator(bb_graph.basic_blocks, bb_graph.bb_out_edges)
pg.imm = imm

cnt = 0
feasible_paths = []
for path in pg.generate_paths(start_addr):
    cnt += 1

    path.log(imm)
    if not prune_paths:
        continue

    p_walker = PathWalker(imm, debug=True)
    try:
        p_walker.walk(path)
        feasible_paths.append(path)
    except UnsatPathConditionException, e:
        imm.log("%s" % str(e))
```

PATHOGEN.PY # FILTERING INVALID PATHS

Check path taken condition

Check path not taken condition

```
def analyzeJccNoFollow(self, condition, finaladdress):
    if self.check_jcc_taken:
        self.state.solver.push()
        # Check if the jcc can be taken
        ret = self.state.solver.checkUnsat(condition)
        self.state.solver.pop()

        if not ret:
            self.jcc_taken = True
        else:
            self.jcc_taken = False
        # assert the condition as true and set everything for analysis
        self.jcc_taken_condition = condition

    if self.check_jcc_not_taken:
        self.state.solver.push()
        # Check if the fall-through is possible
        not_cond = self.state.solver.boolNotExpr(condition)
        ret = self.state.solver.checkUnsat(not_cond)
        self.state.solver.pop()

        if not ret:
            self.jcc_not_taken = True
        else:
            self.jcc_not_taken = False

        self.jcc_not_taken_condition = not_cond
```

pathogen.py # filtering invalid paths

DEMO

INFRASTRUCTURE

SequenceAnalyzer – Models x86 as operations over a set of SMT primitives.

Solver – Ctypes interface to the CVC3 SMT solver API. Supports a variety of theories including quantifier free, bit-vector arithmetic, linear arithmetic etc.

CodeGraph/PathGenerator – Purely static CFG building and path generation.

PathWalker – SMT based path traversal. Each conditional jump is checked for feasibilty and the path discarded if not SAT.

Part II: One Hammer, Many Nails

ROP

↓

Path Filtering

↓

Finding variable bounds

↓

Finding integer overflows

↓

Loops and solvers

↓

Performance/Scaling

VARBOUNDS.PY # FINDING VARIABLE RANGES

```
MOV ESI,EDX
SHR ESI,4
XOR ESI,ECX
AND ESI,0F0F0F0F
XOR ECX,ESI
SHL ESI,4
XOR EDX,ESI
PUSH EDI
MOV ESI,ECX
SHL ESI,12
XOR ESI,ECX
AND ESI,CCCC0000
MOV EDI,ESI
SHR EDI,12
XOR EDI,ESI
XOR ECX,EDI
MOV ESI,EDX
SHL ESI,12
XOR ESI,EDX
AND ESI,CCCC0000
MOV EDI,ESI
SHR EDI,12
XOR EDI,ESI
XOR EDX,EDI
MOV ESI,EDX
SHR ESI,1
XOR ESI,ECX
AND ESI,55555555
XOR ECX,ESI
ADD ESI,ESI
XOR EDX,ESI
MOV ESI,ECX
SHR ESI,8
XOR ESI,EDX
AND ESI,0FF00FF
XOR EDX,ESI
SHL ESI,8
XOR ECX,ESI
MOV ESI,EDX
SHR ESI,1
XOR ESI,ECX
MOV EAX,DWORD PTR SS:[EBP-
AND ESI,55555555
XOR ECX,ESI
ADD ESI,ESI
XOR EDX,ESI
MOV EDI,EDX
SHR EDI,0C
AND EDI,0FF0
MOV ESI,ECX
AND ESI,F000000F
OR EDI,ESI
MOV ESI,EDX
AND ESI,0FF
SHR EDI,4
SHL ESI,10
OR EDI,ESI
AND EDX,0FF00
OR EDI,EDX
AND ECX,0FFFFFFF
XOR EDX,EDX
MOV DWORD PTR SS:[EBP-8],E
MOV BL,BYTE PTR DS:[EDX+7
TEST BL,BL
MOV EDX,EDI
MOV ESI,ECX
```

VARBOUNDS.PY # FINDING VARIABLE RANGES

Given we control EDX at the start what range of values may ESI have at the end?

```
MOV ESI,EDX
SHR ESI,4
XOR ESI,ECX
AND ESI,0F0F0F0F
XOR ECX,ESI
SHL ESI,4
XOR EDX,ESI
PUSH EDI
MOV ESI,ECX
SHL ESI,12
XOR ESI,ECX
AND ESI,CCCC0000
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AND ESI,CCCC0000
MOV EDI,ESI
SHR EDI,12
XOR EDI,ESI
XOR EDX,EDI
MOV ESI,EDX
SHR ESI,1
XOR ESI,ECX
AND ESI,55555555
XOR ECX,ESI
ADD ESI,ESI
XOR EDX,ESI
MOV ESI,ECX
SHR ESI,8
XOR ESI,EDX
AND ESI,0FF00FF
XOR EDX,ESI
SHL ESI,8
XOR ECX,ESI
MOV ESI,EDX
SHR ESI,1
XOR ESI,ECX
MOV EAX,DWORD PTR SS:[EBP-
AND ESI,55555555
XOR ECX,ESI
ADD ESI,ESI
XOR EDX,ESI
MOV EDI,EDX
SHR EDI,0C
AND EDI,0FF0
MOV ESI,ECX
AND ESI,F000000F
OR EDI,ESI
MOV ESI,EDX
AND ESI,0FF
SHR EDI,4
SHL ESI,10
OR EDI,ESI
AND EDX,0FF00
OR EDI,EDX
AND ECX,0FFFFFFF
XOR EDX,EDX
MOV DWORD PTR SS:[EBP-8],E
MOV BL,BYTE PTR DS:[EDX+7
TEST BL,BL
MOV EDX,EDI
MOV ESI,ECX
```

VARBOUNDS.PY # FINDING VARIABLE RANGES

Given we control EDX at the start what range of values may ESI have at the end?

Dumb solution? For an *n* bit output register *r* create 2^n formulae, one for each value *v* of *r. C* in this case is the constraint *r == v*

```
MOV ESI,EDX
SHR ESI,4
XOR ESI,ECX
AND ESI,0F0F0F0F
XOR ECX,ESI
SHL ESI,4
XOR EDX,ESI
PUSH EDI
MOV ESI,ECX
SHL ESI,12
XOR ESI,ECX
AND ESI,CCCC0000
MOV EDI,ESI
SHR EDI,12
XOR EDI,ESI
XOR ECX,EDI
MOV ESI,EDX
SHL ESI,12
XOR ESI,EDX
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XOR EDX,EDI
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XOR ECX,ESI
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MOV ESI,ECX
SHR ESI,8
XOR ESI,EDX
AND ESI,0FF00FF
XOR EDX,ESI
SHL ESI,8
XOR ECX,ESI
MOV ESI,EDX
SHR ESI,1
XOR ESI,ECX
MOV EAX,DWORD PTR SS:[EBP-
AND ESI,55555555
XOR ECX,ESI
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XOR EDX,ESI
MOV EDI,EDX
SHR EDI,0C
AND EDI,0FF0
MOV ESI,ECX
AND ESI,F000000F
OR EDI,ESI
MOV ESI,EDX
AND ESI,0FF
SHR EDI,4
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OR EDI,ESI
AND EDX,0FF00
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```
mov ebx, eax
add ebx 0xFF
and ebx, 0xFF
```

```
MOV ESI,EDX
SHR ESI,4
XOR ESI,ECX
AND ESI,0F0F0F0F
XOR ECX,ESI
SHL ESI,4
XOR EDX,ESI
PUSH EDI
MOV ESI,ECX
SHL ESI,12
XOR ESI,ECX
AND ESI,CCCC0000
MOV EDI,ESI
SHR EDI,12
XOR EDI,ESI
XOR ECX,EDI
MOV ESI,EDX
SHL ESI,12
XOR ESI,EDX
AND ESI,CCCC0000
MOV EDI,ESI
SHR EDI,12
XOR EDI,ESI
XOR EDX,EDI
MOV ESI,EDX
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XOR ESI,ECX
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SHR ESI,8
XOR ESI,EDX
AND ESI,0FF00FF
XOR EDX,ESI
SHL ESI,8
XOR ECX,ESI
MOV ESI,EDX
SHR ESI,1
XOR ESI,ECX
MOV EAX,DWORD PTR SS:[EBP+
AND ESI,55555555
XOR ECX,ESI
ADD ESI,ESI
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AND EDI,0FF0
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AND ESI,F000000F
OR EDI,ESI
MOV ESI,EDX
AND ESI,0FF
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```
mov ebx, eax
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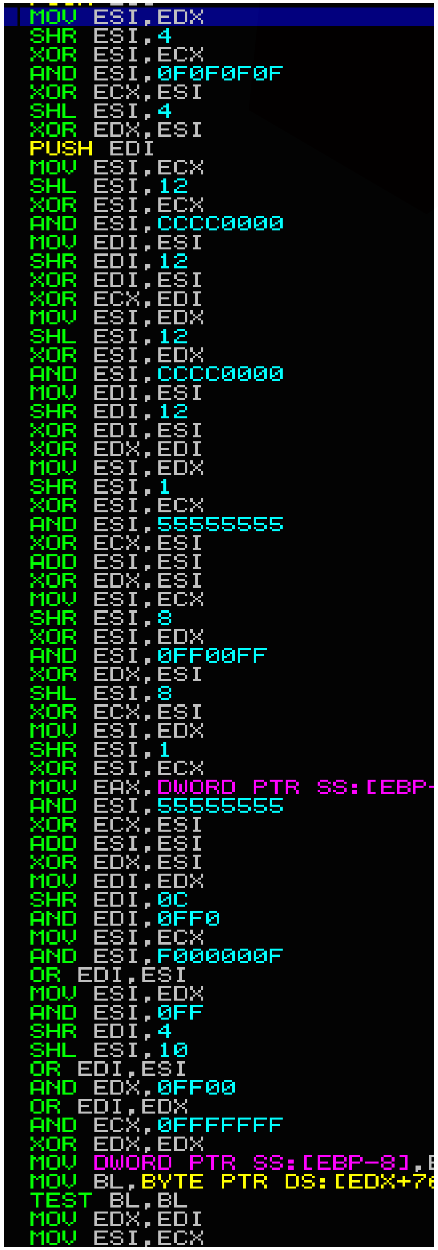
and ebx, 0xFF
```

F: (= ebx^0, eax^0) ^ (= ebx^1, (+ ebx^0, 0xFF) ^
(= ebx^2, (AND ebx^1, 0xFF))



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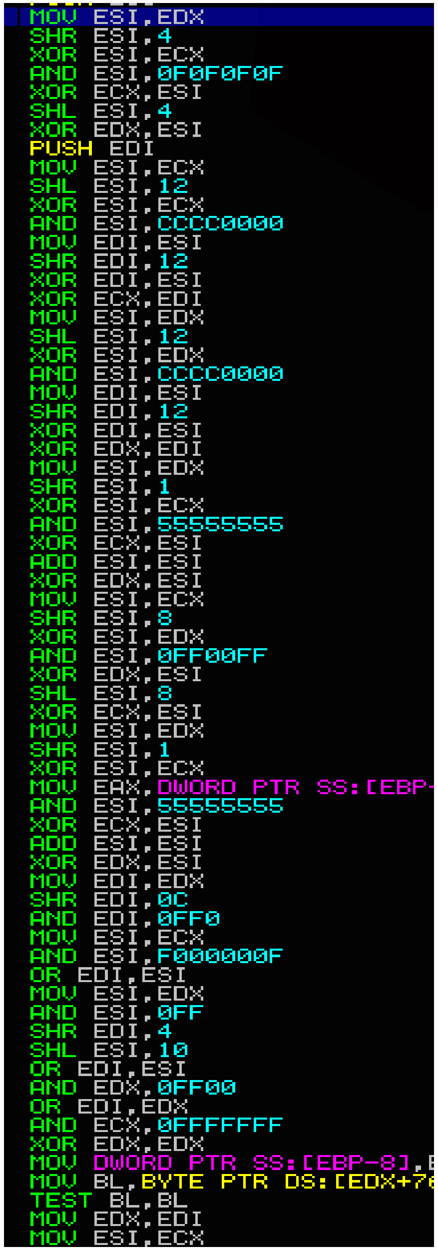

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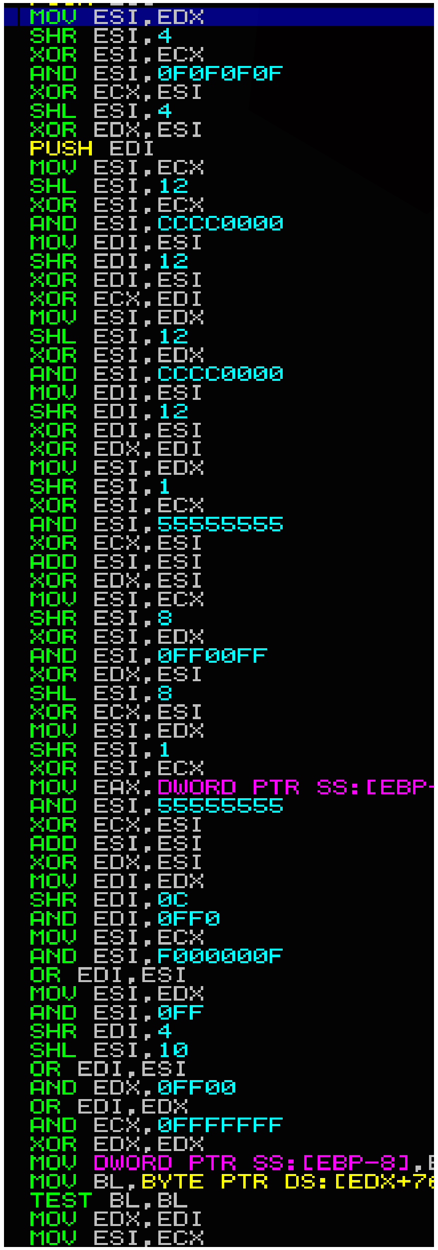
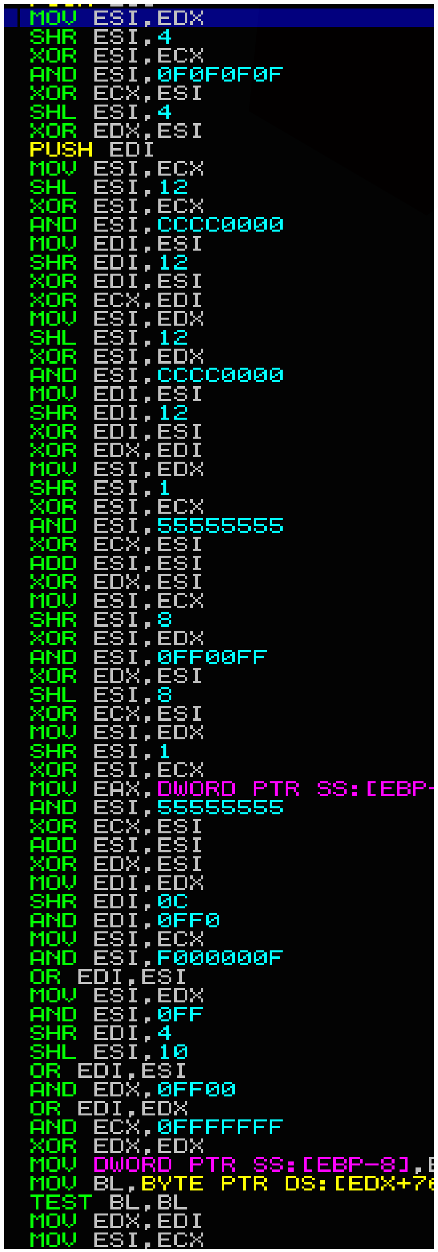
C: (= ebx^2, x) for all x in [0, .., 2^n]

Every SAT result indicates that *x* is a possible output value and *getConcreteModel()* gives the value required in EDX to achieve it



VARBOUNDS.PY # FINDING VARIABLE RANGES

Better solution? Use bucket ranges. Split the range 0, 2^n into buckets and make C *lower_bound* <= *v* < *upper_bound* for each bucket. Direct == queries for all values in the valid buckets. Same worst case running time. Performs far better in many cases.



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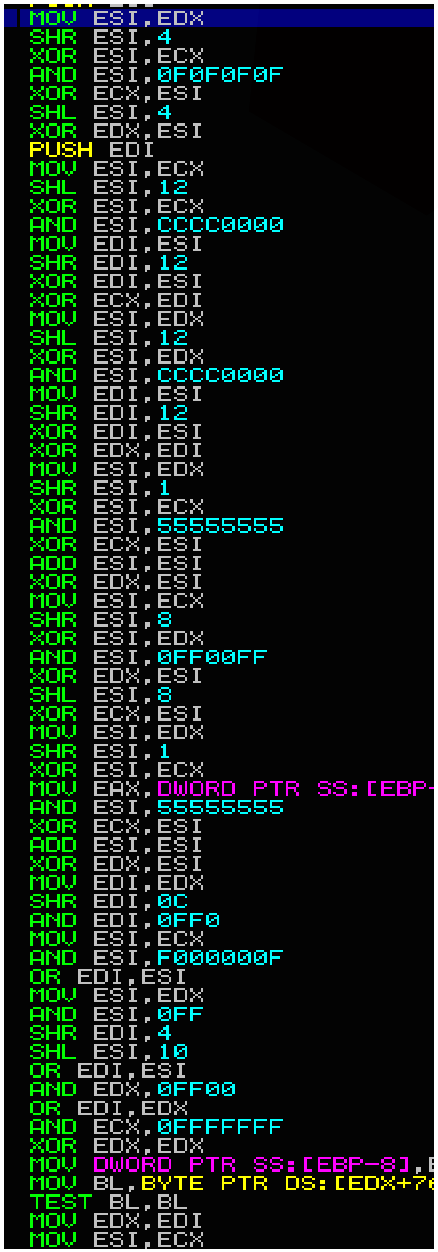
Better still? For each bit *b* in *r* check if *b == 1* is satisfiable in order to find an absolute upper/lower bound before the previous stage. 32 queries, works well.



varbounds.py # Finding variable ranges

DEMO

varbounds.py # Finding variable ranges

We're still being rather dumb.

VARBOUNDS.PY # FINDING VARIABLE RANGES

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```
add eax, 10
mul ebx
rol ebx, ecx
```

Pure SMT solutions tend to have difficulty seeing the forest for the trees.

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Often worth considering using an initial static analysis run first to limit cases and use a solver to resolve any remaining imprecision.

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and ebx, ecx
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```
mov ebx, eax
add ebx, 0xFF
and ebx, 0xFF
shl ebx, 0x10
and ebx, ecx
```

```
cmp eax, 0xFF
jbe EXIT
```

Quite a lot of latent information in arithmetic, logical and conditional branching instructions that can be extracted at varying expense

Abstract Interpretation in Brief and Vague "Detail"

Abstract Interpretation is a useful framework in many situations e.g. for *varbounds.py* and logical operators

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Abstract Interpretation is a useful framework in many situations e.g. for *varbounds.py* and logical operators

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2) Build an abstraction function for each concrete instruction

Three valued logic
{
MUST_BE_SET,
CANT_BE_SET,
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}

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Three valued logic
{
MUST_BE_SET,
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}

AND # f(x, y)
f(MBS, MBS) -> MBS
f(MBS, CBS) -> CBS
f(MBS, PBS) -> PBS
f(CBS, *) -> CBS
f(PBS, MBS) -> PBS
f(PBS, PBS) -> PBS
f(PBS, CBS) -> CBS

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Similar to our single bit queries but often far less computationally complex. In general makes many more problems tractable that a pure SMT based solution can't handle efficiently.

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Abstract Interpretation in Brief and Vague "Detail"

Initial state: $EAX_{0\text{-}31}$ = PBS, $ECX_{0\text{-}7}$ = PBS, $ECX_{8\text{-}31}$ = MBS

```
mov ebx, eax
add ebx, 0xFF
and ebx, 0xFF
shl ebx, 0x10
and ebx, ecx
```

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```
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```

mov ebx, eax ; EBX_{0-31} = PBS

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```
mov ebx, eax
add ebx, 0xFF
and ebx, 0xFF
shl ebx, 0x10
and ebx, ecx
```

```
mov ebx, eax   ; EBX0-31 = PBS

add ebx, 0xFF ; NOP in this domain
```

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mov ebx, eax ; EBX_{0-31} = PBS

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and ebx, 0xFF ; EBX_{0-7} = PBS, EBX_{8-31} = CBS

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mov ebx, eax ; EBX_{0-31} = PBS

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; $EBX_{24-31,\ 0-15}$ = CBS

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Part II: One Hammer, Many Nails

ROP

Path Filtering

Finding variable bounds

Finding integer overflows

Loops and solvers

Performance/Scaling

FIND_INT_OVERFLOW.PY # WHAT IT SOUNDS LIKE

SequenceAnalyzer() takes a list of bug checkers that will be called on each instruction (although if we use it through *PathWalker()* we get path filtering as well)

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```
def check_ins(self, sa, ins):
    res = None

    op = operations.operation(ins)
    disasm_str = op.removeLockPrefix()

    if disasm_str == "ADD":
        if self.debug:
            self.imm.log("check_ins (%s): ADD" % hex(ins.getAddress()),
                         ins.getAddress())
        solver = sa.state.solver

        dst = sa.buildState(ins.operand[0])
        src = sa.buildState(ins.operand[1])
        dst_val = sa.getValueFromState(dst)
        src_val = sa.getValueFromState(src)

        res_64 = solver.addExpr(dst_val, src_val, 64)

        gt_expr = solver.gtExpr(res_64, solver.constExpr(MAX_INT_32))
        status = solver.checkSat(gt_expr)

        if status:
            if self.debug:
                self.imm.log("check_ins (%s): Bug found" % \
                             hex(ins.getAddress()))
            res = BugCheckResults(ins.getAddress(),
                                  solver.getConcreteModel())
```

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Check if the result is > 2^{32}

```
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find_int_overflow.py # what it sounds like

DEMO

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Necessary to use lazy warning of bugs e.g. where the result of an overflow is used as opposed to where it occurs. Many overflows are later checked for and benign.

```
unsigned a, alloc_size;
alloc_size = get_from_user();

a = alloc_size + 1;

if (alloc_size > 0xff)
        goto exit;

x = malloc(a);
```

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a = alloc_size + 1;

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```

See Julien Vanegue's HES 2009 talk for a more developed idea focusing on integer overflows on the size parameter to heap allocations

INFRASTRUCTURE

SequenceAnalyzer – Models x86 as operations over a set of SMT primitives.

Solver – Ctypes interface to the CVC3 SMT solver API. Supports a variety of theories including quantifier free, bit-vector arithmetic, linear arithmetic etc.

CodeGraph/PathGenerator – Purely static CFG building and path generation.

PathWalker – SMT based path traversal. Each conditional jump is checked for feasibilty and the path discarded if not SAT.

BugChecker – Subclasses provide the check_ins method which will be passed the SMT context representing the current path.

Part II: One Hammer, Many Nails

ROP

↓

Path Filtering

↓

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↓

Finding integer overflows

↓

Loops and solvers

↓

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Loops however have no natural representation. Only option is to unroll. How?

1) Prove loop bounds

2) Guess loop bounds.

3) Approximate loop bounds

Part II: One Hammer, Many Nails

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↓

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↓

Loops and solvers

↓

Performance/Scaling

PERFORMANCE/SCALING

Scaling of raw solver capabilities[1]

[1] I'm currently gathering results for some well defined instances. Should be up on http://seanhn.wordpress.com soon

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Whole program analysis – not really my interest, realistically not feasible for many tasks we care about e.g. general bug detection in real programs (in both dev time and scalability, we're not a university research group)

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PERFORMANCE/SCALING

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More investigation required to discover typical formula complexity for general RE/Exploit dev problems. SMT-COMP has no such tests.

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Some problems are naturally ported to this domain (path filtering) while others (variable bound checking) are more of a cludge. More still (finding arithmetic flaws) suit collaboration with basic static analysis and a human.


QUESTIONS?
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