GCC Plugins
Die by the Sword

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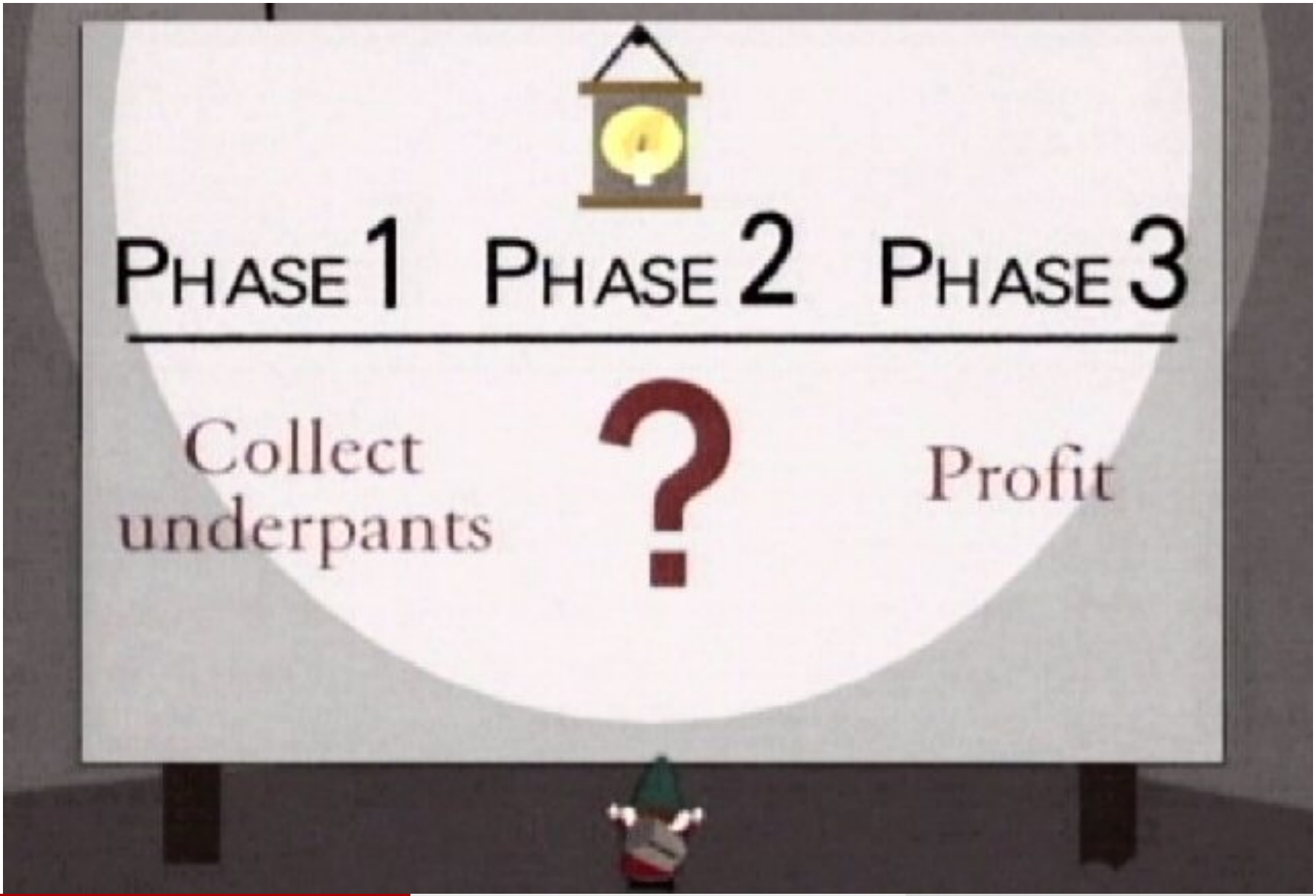
Compiler, Goatse, and Code Transformation, Oh My!



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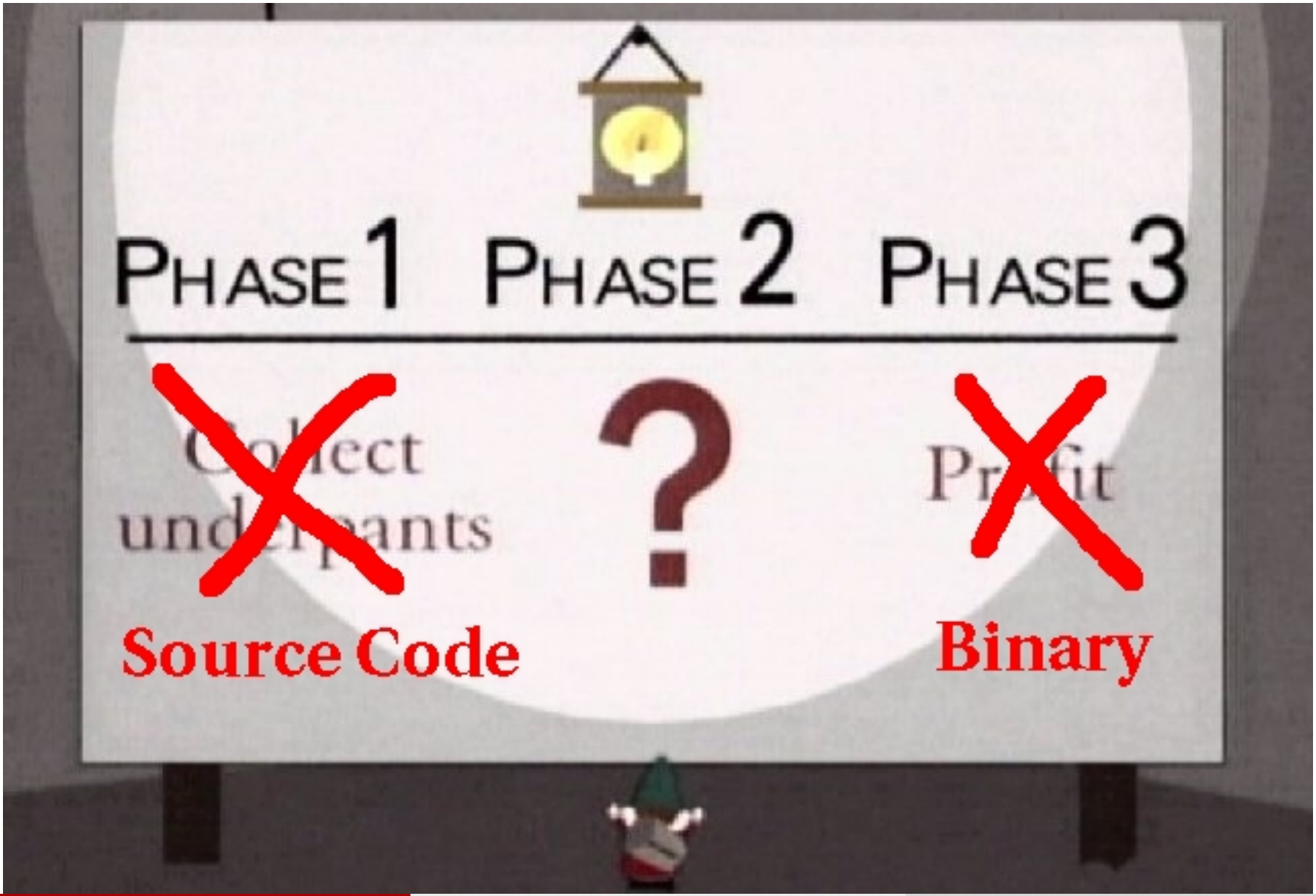


Compiler, Goatse, and Code Transformation, Oh My!

Compiler 101

Compiler 101

- Transforms human readable/parseable text into a machine readable executable.
- Source Code (human friendly) $\Rightarrow$ Object Code (machine friendly).
- Lexing $\Rightarrow$ Scanning $\Rightarrow$ Transformation.
- Often accept many input languages and multiple output targets.
- {C, C++, Go, Fortran} $\Rightarrow$ {x86, ARM, MIPS, ATmega}.
- Optimization *(e.g. loop-unrolling, basic-block reordering, dead code elimination)*.
- Source Code Error Detection *(e.g. out of bounds)*.

Syntax and Semantics

Position Sep 2011	Position Sep 2010	Delta in Position	Programming Language	Ratings Sep 2011	Delta Sep 2010	Status
1	1	=	Java	18.761%	+0.85%	A
2	2	=	C	18.002%	+0.86%	A
3	3	=	C++	8.849%	-0.96%	A
4	6	↑↑	C#	6.819%	+1.80%	A
5	4	↓	PHP	6.596%	-1.77%	A
6	8	↑↑	Objective-C	6.158%	+2.79%	A
7	5	↓↓	(Visual) Basic	4.420%	-1.38%	A
8	7	↓	Python	4.000%	-0.58%	A
9	9	=	Perl	2.472%	+0.03%	A
10	11	↑	JavaScript	1.469%	-0.20%	A
11	10	↓	Ruby	1.434%	-0.47%	A
12	12	=	Delphi/Object Pascal	1.313%	-0.27%	A
13	24	↑↑↑↑↑↑↑↑↑↑	Lua	1.154%	+0.60%	A
14	13	↓	Lisp	1.043%	-0.04%	A
15	15	=	Transact-SQL	0.860%	+0.09%	A
16	14	↓↓	Pascal	0.845%	+0.06%	A-
17	20	↑↑↑	PL/SQL	0.720%	+0.08%	A--
18	19	↑	Ada	0.682%	+0.01%	B
19	17	↓↓	RPG (OS/400)	0.666%	-0.05%	B
20	30	↑↑↑↑↑↑↑↑↑↑	D	0.609%	+0.20%	B

Figure: Sept 2011 Language Popularity Source: *http://www.tiobe.com*

Syntax and Semantics: Example

What do you see here?

Syntax and Semantics

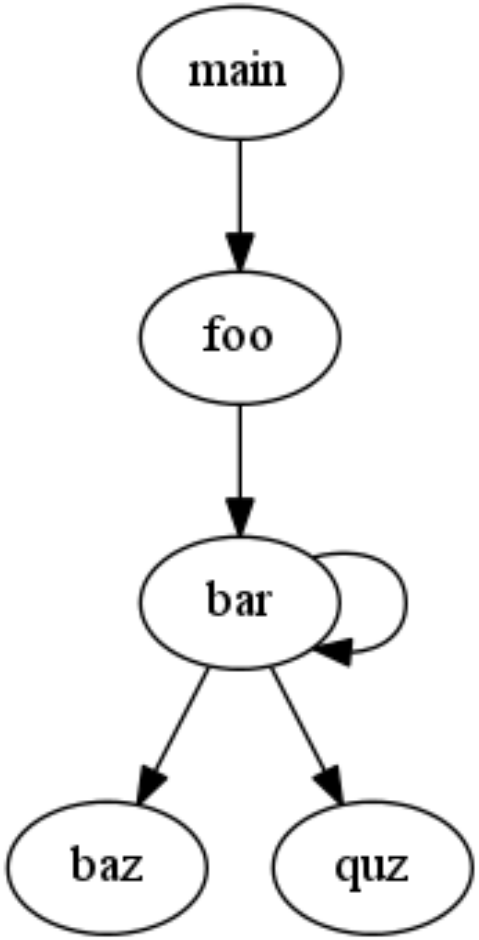
Syntax and Semantics

- Syntax – Structure and style of source code.
- Semantics – Meaning of source code.
- Compilers can modify syntax (optimizations) but should never change the meaning of a program.

Call Graph

- Which functions call which other functions.
- Node – Function.
- Edge – Calling relationship.
- Example:

```
void quz(void) { }

void bar(void)
{
    baz();
    quz();
    bar();
}

void foo(void)
{
    bar();
}

int main(void)
{
    foo();
}
```



Control Flow Graph

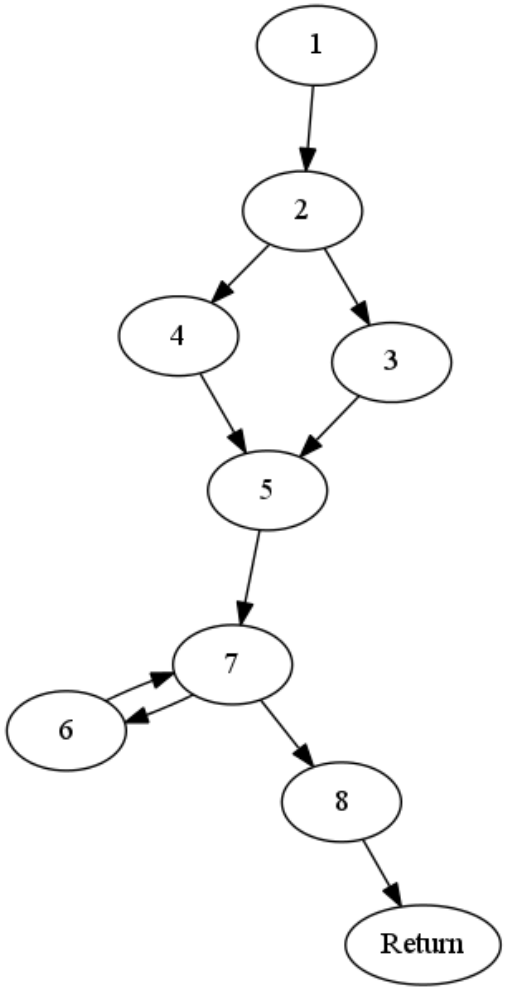
Control Flow Graph

- Shows paths of execution within a program (reachability).
- Considers branching constructs (e.g. if/else, loops).
- Basic Block – Block of execution where no jumps occur.
- Node – Basic Block.
- Edge – Connection between basic blocks.

Control Flow Graph

```
void foo(int x)
{
    int i, sum;

    if (x == 2)
      bar();
    else
      baz();

    for (i=0; i<100; ++i)
      sum += silvio();
}
```

```
foo (int x) {
  int i, sum;
<bb 2>:
  if (x == 2) goto <bb 3>;
  else goto <bb 4>;

<bb 3>:
  bar ();
  goto <bb 5>;

<bb 4>:
  baz ();

<bb 5>:
  i = 0;
  goto <bb 7>;

<bb 6>:
  sum += sum;
  ++i;

<bb 7>:
  if (i <= 99) goto <bb 6>;
  else goto <bb 8>;

<bb 8>:
  return;
}
```



Static Analysis

Static Analysis

- Makes use of the compiler data structures.
- Figure out what's going on at compile time.
- Can be used for implementing optimizations.
- Bad code detection.
- *Intra*procedural – Analysis within a single function.
- *Inter*procedural – Analysis between functions and their relationships.

Malware Obfuscation Techniques

Figure: Source: *http://www.shirtoid.com*

Malware Obfuscation Techniques

Malware Detection Aversion

- Techniques
  - Polymorphism
  - Metamorphism
  - Junk Instructions
- *Why?* To evade antivirus and malware detection.

Polymorphic and Metamorphic Code

Code Morphism: Polymorphic vs Metamorphic

- The morphism here is *not* in the sense of polymorphic functions or data types.
- *Morphism* – Mutating code.
- *Poly*morphic – Mutating code via encoding/encryption. The code can be dynamically decoded at runtime.
- *Meta*morphic – Mutating code by manipulating how it functions.
- Changes the hash-signature of the binary.
- Avoids signature detection (based on hash).
- Can confuse analysis such as those based on call graphs.

What is the purpose of this?

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mov edi, edi

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mov edi, edi

- Windows begins all functions with this...
- A two byte NOP instruction...
- "Hot-patch point" allowing at runtime for a jump instruction to replace this instruction.

Junk Instructions

Junk Instructions

- Useless operations.
- Have no effect on the result of the application aside from a few spent cycles.
- Change the hash/signature of the binary.
- Essentially no-ops (NOP).
- NOPs are easily detected in disassembly.
- Creating of less obvious no-op operations can be used:
  mov eax, eax
  mul 0x1, ebx
  etc...
- Caution: Be careful not to generate divide-by-zero exceptions via division and modulus operations.
- Caution: If you seed the random number generator, e.g. srand(), you might confuse the original program if it happens to use a static seed.
- Time can be used as a somewhat poor source of random value, but it might be all you need.

Junk Instructions pt.2

Junk Instructions

- Inline assembly can be generated, but renders the resulting code architecture specific.
- By creating junk instructions/statements via GIMPLE, we can create architecture independent code.

GCC and Plugins

GCC: GNU Compiler Collection

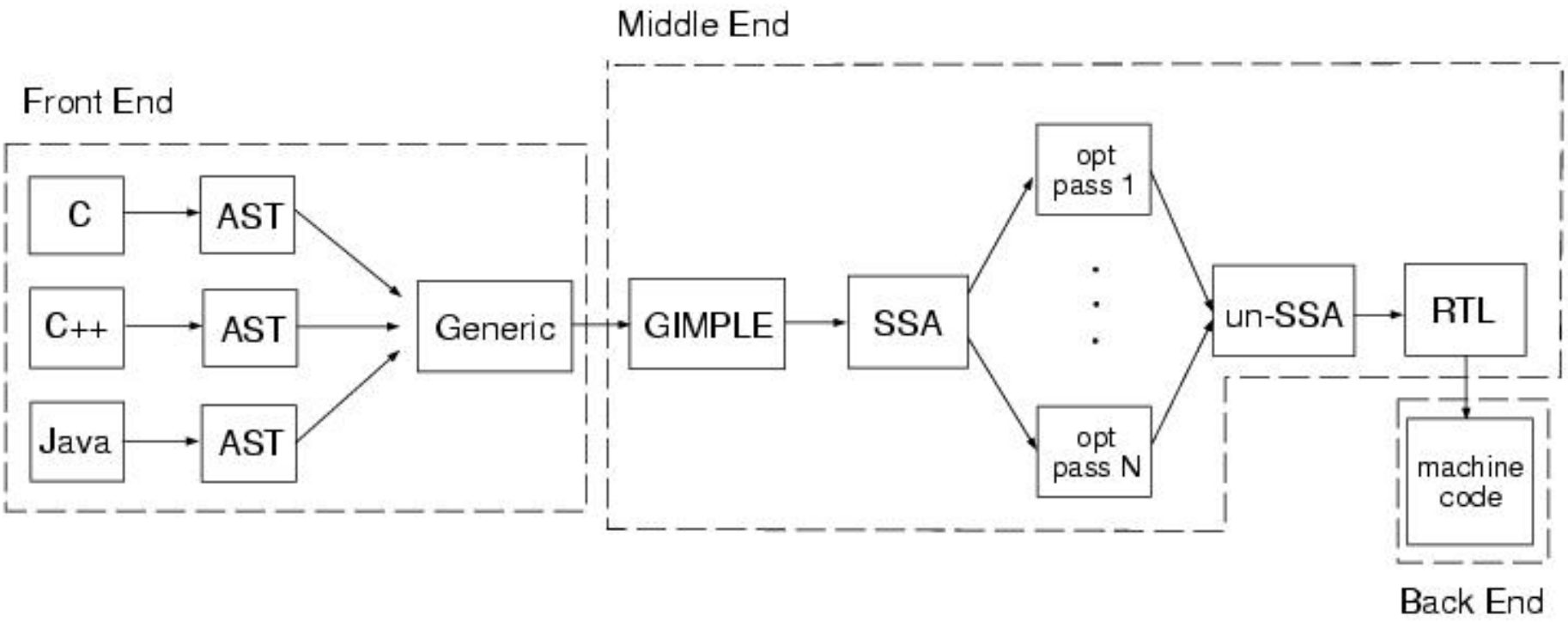


Figure: GCC Architecture:
http://en.wikibooks.org/wiki/GNU_C_Compiler_Internals/GNU_C_Compiler_Architecture

GIMPLE

GIMPLE

- GCC's intermediate language.
- Input languages can output GIMPLE and then GCC optimization and analysis passes can operate on this language agnostic representation.
- A GIMPLE statement consists of a three-address code where lhs, op1, and op2 are the addresses
  GIMPLE assignment statement: lhs = op1 + op2

GCC Plugins

Plugins

- Implemented in GCC version 4.5 and later (April 2010).
- Allows for creation of optimization and analysis passes.
- Portable (shared ELF object file).
- Allows for quick compiler feature prototyping; no need to recompile the entire compiler.
- Can operate on GIMPLE or RTL.
- Simple to use: *gcc ¡source¿ -fplugin=./my_plugin.so*

Plugin Types

Plugin Types

- *GIMPLE* – Intraprocedural, operates per function. Can be used interprocedurally.
- *IPA* – Interprocedural, per function and operates on callgraph.
- *RTL* – Operates on Register Transfer Language. Intermediate language which is used to match a machine description and eventual output as assembly.
- *PLUGIN_PASS_MANAGER* – Allows plugin to execute in different positions of the compilation. *Start of compilation, End of passes, etc*

Plugin Creation Ingredients

Whatcha Need

- GCC 4.5 or greater.
  - Suggested: Build from scratch with debugging symbols and without optimization:
    make BOOT_CFLAGS="-g3 -O0"
- gdb (optional but helps the learning process)
- Coffee.

Plugin Creation Ingredients

Whatcha Need

- GCC 4.5 or greater.
  - Suggested: Build from scratch with debugging symbols and without optimization:
    make BOOT_CFLAGS="-g3 -O0"
- gdb (optional but helps the learning process)
- Coffee.
- Lack of sanity.

Plugin Creation Requirements

Necessary Bits

- Symbol signifying that your plugin adheres to the GPL:
  int plugin_is_GPL_compatible = 1;
- *exec* – Callback tripped when a compiler event is met.
- *gate* – Callback tripped just before *exec* is executed. If the gate returns true, *exec* is executed, otherwise it is skipped.

Plugin Example (nopper)

Simple iteration across all basic blocks in a function, and across all statements within that basic block:

```
    FOR_EACH_BB(bb)
    for (gsi=gsi_start_bb(bb); !gsi_end_p(gsi); gsi_next(&gsi))
      for (i=0; i<nops_per_stmt; ++i)
        insert_nop(gsi);
```

And the routine to insert inline assembly: *mov eax, eax*

```
static void insert_nop(gimple_stmt_iterator gsi)
{
    gimple nop;

    nop = gimple_build_asm_vec(
        "mov %%eax, %%eax", NULL, NULL, NULL, NULL);

    gsi_insert_before(&gsi, nop, GSI_NEW_STMT);
}
```

NOTE: By using inline assembly, we render the resulting code architecture/machine specific. This is changed in the "jpanic" plugin discussed later.

Examples

GOAT-Plugs: GCC Obfuscation Augmentation Tools

GOAT-Plugs: GCC Obfuscation Augmentation Tools
GIT repository: *http://github.com/enferex/GOAT-Plugs*

GOAT-Plugs: GCC Obfuscation Augmentation Tools

- Series of basic GCC plugins to obfuscate your programs.
- nopper – Simple plugin, well commented, a good tutorial. Adds user defined number of junk nops between statements.
- slimer – Inserts function calls to junk functions. The junk function called is chosen pseudo-randomly at runtime.
- jpanic – Creates junk functions with junk instructions, and places them through out the program.
- munger – Encodes read-only strings at compile time, and decodes them at runtime.

GOAT-Plugs: slimer

Who ya gonna call?

Before (in C)

```
int main(void)
{
    dosomething(2+3);
    return 0;
}
```

After (in GIMPLE)

```
main()
{
dosomething (5);
time_tmp.100_2 = time (0B);
rv_tmp.101_3 = time_tmp.100_2 % 20;
tmp.102_4 = __slimer_get_funcs ();
rv_tmp.101_3 = rv_tmp.101_3 * 8;
fn_tmp.103_5 = tmp.102_4 + rv_tmp.101_3;
the_func_ptr.104_6 = *fn_tmp.103_5;
the_func_ptr.104_6 ();
D.3392_1 = 0;
return D.3392_1;
}
```

What the GIMPLE representation is doing, calling a random function:

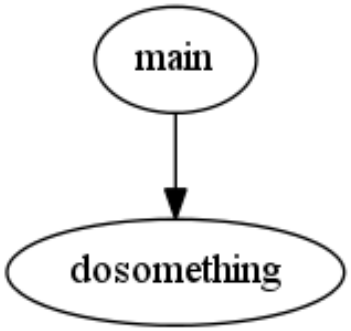
- index = time() modulo number-of-junk-functions
- function-pointer = array-of-junk-functions[index]
- function-pointer()

GOAT-Plugs: jpanic

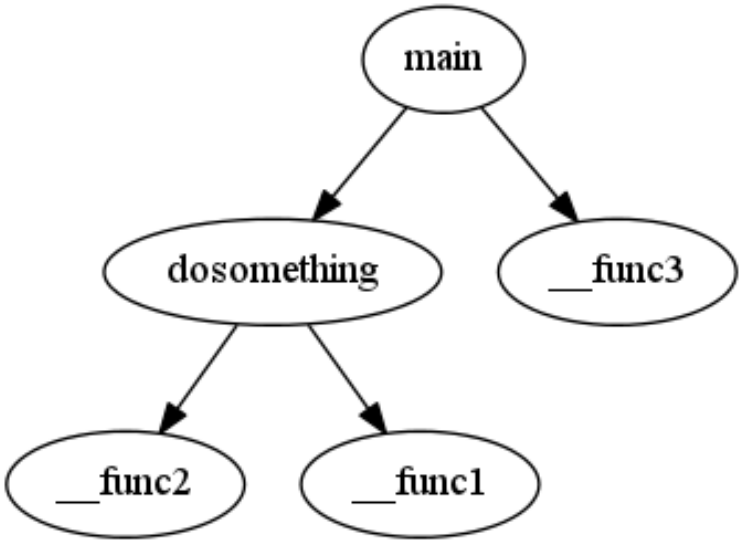
```
static void dosomething(int n)
{
}

int main(void)
{
    dosomething(2+3);
    return 0;
}
```

Call graph: Before



Call graph: After



GOAT-Plugs: jpanic (example 2)

Not the same output as the previous example, but the same input source code.

main() (GIMPLE)

```
main ()
{
int _junk.6;
int _junk.5;
int _junk.4;
int _junk.3;
int D.3252;

<bb 2>:
__func1 ();
dosomething (5);
D.3255_1 = _junk.3_2 + _junk.4_3;
D.3252_1 = 0;
D.3255_1 = _junk.5_4 * _junk.6_5;
return D.3252_1;
}
```

main() (64bit x86 ASM)

```
0x0000000000400462: push   %rbp
0x0000000000400463: mov    %rsp,%rbp
0x0000000000400466: push   %r14
0x0000000000400468: push   %r13
0x000000000040046a: push   %r12
0x000000000040046c: push   %rbx
0x000000000040046d: mov    $0x0,%eax
0x0000000000400472: callq  0x400499 <__func1>
0x0000000000400477: mov    $0x5,%edi
0x000000000040047c: callq  0x400454 <dosomething>
0x0000000000400481: lea    (%r14,%r13,1),%eax
0x0000000000400485: mov    $0x0,%eax
0x000000000040048a: mov    %r12d,%eax
0x000000000040048d: imul   %ebx,%eax
0x0000000000400490: pop    %rbx
0x0000000000400491: pop    %r12
0x0000000000400493: pop    %r13
0x0000000000400495: pop    %r14
0x0000000000400497: pop    %rbp
0x0000000000400498: retq
```

GOAT-Plugs: munger

Before (in C)

```
Command:
    gcc test.c

Source:
int main(void)
{
const char *notShellCode = "Ruxcon2011!";
printf("%s\n", notShellCode);
return 0;
}

GNU strings dump:
    /lib/ld-linux-x86-64.so.2
    __gmon_start__
    libc.so.6
    puts
    __libc_start_main
    GLIBC_2.2.5
    fff.
    l$ L
    t$(L
    |$0H
    Ruxcon2011!
```

After (in GIMPLE)

```
Command:
    gcc -fplugin=./munger.so \
        munger_builtins.o test.c
Source:
main ()
{
const char * notShellCode;
int D.3250;
<bb 2>:
FOO.0 = __decode(FOO.0, "<GIBBERISH>", 12);
notShellCode_1 = FOO.0;
__builtin_puts (notShellCode_1);
D.3250_2 = 0;
return D.3250_2;
}

GNU strings dump:
    __gmon_start__
    libc.so.6
    puts
    calloc
    __libc_start_main
    GLIBC_2.2.5
    fff.
    l$ L
    t$(L
    |$0H
```

GOAT-Plugs: hatch

Hatch

- Just an example plugin.
- Remote code execution.
- Inserts a netcat socket call into the binary.
- Also creates a netcat socket when building.
- Suppose target builds with "sudo make"... remote root control.
- Example, give your backdoor plugin to a friend. Tell them to build some simple c-code...

GOAT-Plugs: hatch in practice

Hatch example

```
DerpDerpUser$> sudo make
DerpDerpUser$>
```

GOAT-Plugs: hatch in practice

Hatch example

```
DerpDerpUser$> sudo make
DerpDerpUser$>
```

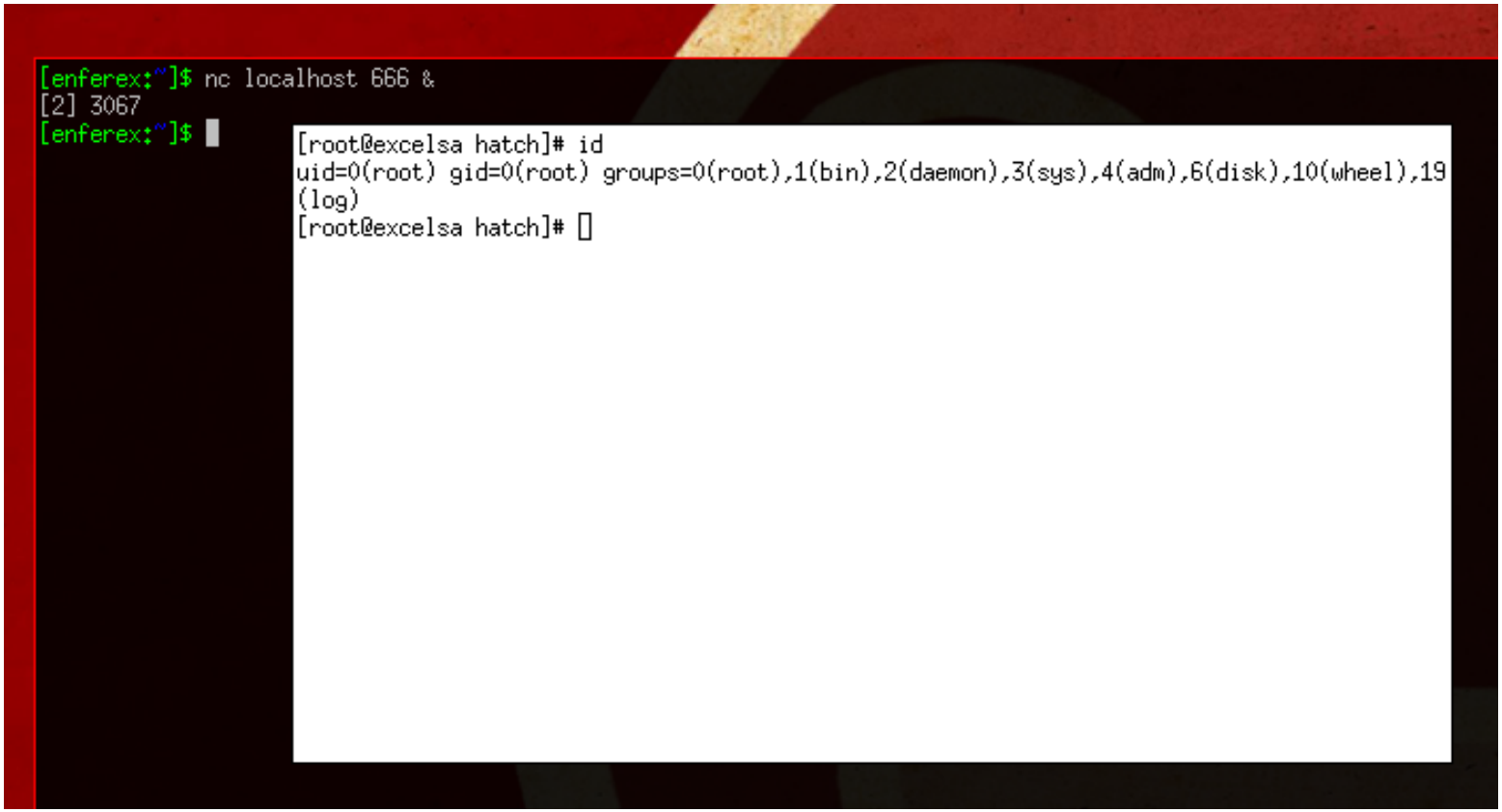
```
MaliciousUser$> nc host.target.address port &
MaliciousUser$>
```

GOAT-Plugs: hatch in practice

Hatch example

```
DerpDerpUser$> sudo make
DerpDerpUser$>
```

```
MaliciousUser$> nc host.target.address port &
MaliciousUser$>
```



Fork Me!

http://github.com/enferex/GOAT-Plugs

Shoutouts

Special Thanks:

Ruxcon crew, JPanic (morphism and junk instruction guru), 757 Labs, wulfpax

Resources (1)

- Tutorial: http://lwn.net/Articles/459982/
- Documentation: http://gcc.gnu.org/onlinedocs/gccint/
- GCC: http://gcc.gnu.org
- GOAT-Plugs: https://github.com/enferex/GOAT-Plugs
- Slides: http://users.757.org/~enferex/enferex_ruxcon2011.pdf

Resources (2)

Technical Resources

- http://en.wikipedia.org: Compilers, Lexing, Control Flow Graph, Call Graph
- http://en.wikibooks.org/wiki/GNU_C_Compiler_Internals/GNU_C_Compiler_Architecture
- http://www.f-secure.com/en_EMEA-Labs/virus-encyclopedia/encyclopedia/polymorphism.html
- http://jkeohan.wordpress.com/2010/04/30/using-netcat-to-spawn-a-remote-shell/
- http://blogs.msdn.com/b/ishai/archive/2004/06/24/165143.aspx (Windows hot-patch)
- http://www.tiobe.com/index.php/content/paperinfo/tpci/index.html (Language Popularity)
- http://lwn.net/Articles/459982/ (Intro to plugin creation)

Other Resources:

- GIMP: http://www.gimp.org
- Inkscape: http://www.inkscape.org
- http://boingboing.net/2007/06/04/london-2012-olympic.html (Olympic graphic)
- http://www.shirtoid.com (Transformers graphic)
- http://www.queuefull.net/~bensons/graphics/UnderpantsGnomesPlan.jpg (South Park graphic)
- http://en.wikipedia.org/wiki/Magic_Johnson

Questions

Questions?

Pay no attention to that man behind the curtain!
The Great Oz has spoken!
-The Wizard of Oz