Interprocedural Analysis

Basic Concepts and Why?

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Why bother?

- Most of the programs are complex
    - Not just big chunk of code
    - Lots of cooperating functions
    - Each fuction has impact on program functionality

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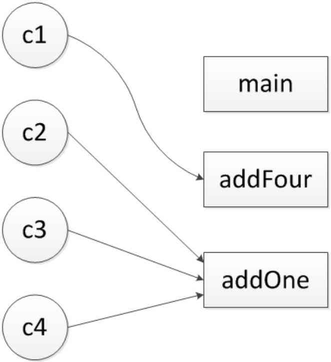
  - Further Code Analysis (Virtual Methods, Pointer Analysis, etc.)
  - and most of all, it is FUN

Basic notations

- **Call Graph** = representation of function calls:



```
   int main() {
c1:  returned = addFour(0);
     if(returned == 5) {
       return 1;
     }
     return 0;
   }

   int addOne(int i) {
     return i+1;
   }

   int addThree(int j) {
c2:   int k = addOne(1);
c3:   int l = addOne(0);
c4:   int m = addOne(0);
      return j+k+l+m;
   }
```

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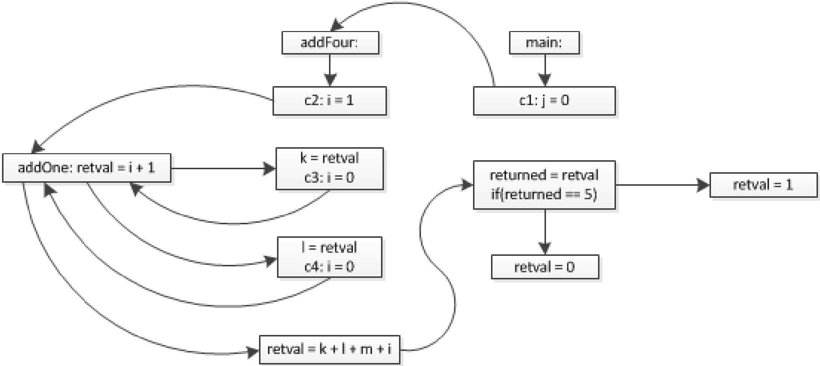

Call strings

- Context can be described by its call site
- **Call string** = part of the call stack contents
- ***k*-limiting context analysis** = only *k* most immediate call sites create the call string

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     return j+k+l+m;
  }
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- Context can be described by its call site
- **Call string** = part of the call stack contents
- ***k*-limiting context analysis** = only *k* most immediate call sites create the call string
- So we get these call strings:
    - (c1, c2)
    - (c1, c3)
    - (c1, c4)

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int main() {
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c2:   int k = addOne(1);
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c4:   int m = addOne(0);
      return j+k+l+m;
   }
```

Cloning Based

- For every function call, one unique context, one unique function
- No confusion, loads of code.

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    int main() {
c1: returned = addFour(0);
      if(returned == 5)
         return 1;
      return 0;
    }

    int addOne1(int i) {
      return i+1;
    }

    int addOne2(int i) {
      return i+1;
    }

    int addOne3(int i) {
      return i+1;
    }

    int addThree(int j) {
c2:   int k = addOne1(1);
c3:   int l = addOne2(0);
c4:   int m = addOne3(0);
      return j+k+l+m;
    }
```

Summary-Based Analysis

- Summarization of function behaviour with transfer/flow function
- Minimum of function body analysis
- Can be simplified by merging caller informations by meet operator
- After summary-analysis we clone functions on its basis

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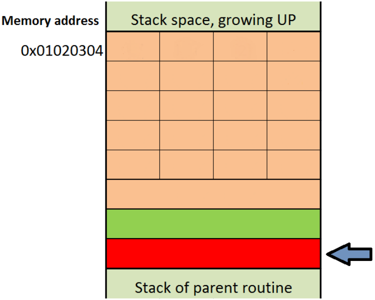
    int addOne1(int i) {
      return i+1;
    }

    int addOne0(int i) {
      return i+1;
    }

    int addThree(int j) {
c2:    int k = addOne1(1);
c3:    int l = addOne0(0);
c4:    int m = addOne0(0);
       return j+k+l+m;
    }
```

Snippet of vulnerable code



```
void logMeIn(char *login) {
    char l[20];
    // no bounds checked
    strcpy(l, login);
    // .. some more unimportant code
}

int main(int argc, char **argv) {
    logMeIn(argv[1]);
    // ...
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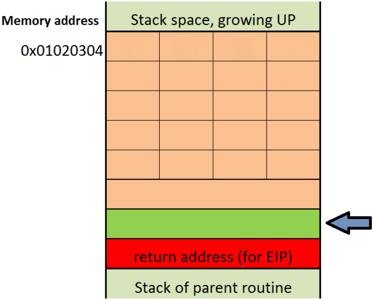

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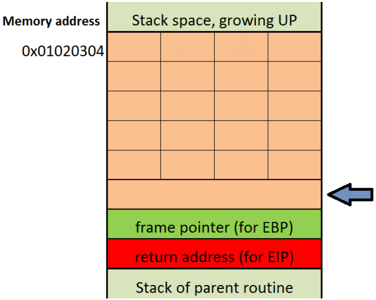

Memory address

0x01020304

Stack space, growing UP

frame pointer (for EBP)

return address (for EIP)

Stack of parent routine

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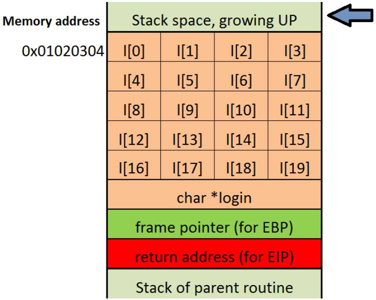

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Stack space, growing UP

l[0]	l[1]	l[2]	l[3]
l[4]	l[5]	l[6]	l[7]
l[8]	l[9]	l[10]	l[11]
l[12]	l[13]	l[14]	l[15]
l[16]	l[17]	l[18]	l[19]

char *login

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Injected Shellcode

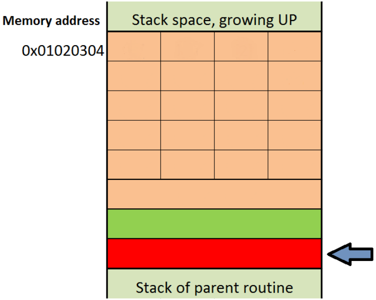
- Lets have following shell code:

```
xor         eax,eax
mov         dx,9998     ; 0x270e
sub         dx,9990     ; 0x2706
mov         al, 55      ; 0x37
int         0x80
```

- After compilation with **NASM** we get:

```
char shellcode[] =
    "\x31\xc0\x66\xba\x0e\x27\x66\x81\xea\x06\x27\xb0\x37\xcd\x80";
```

Snippet of vulnerable code



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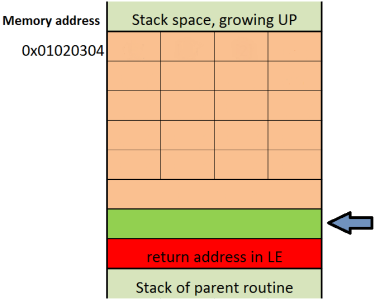

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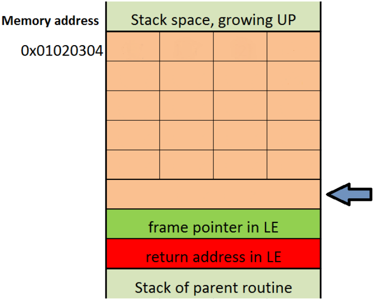

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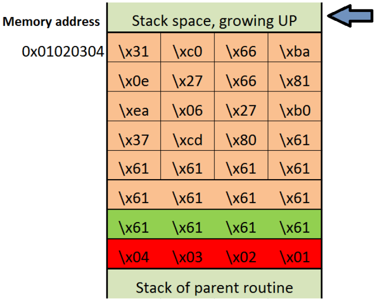

Memory address	Stack space, growing UP			
0x01020304	\x31	\xc0	\x66	\xba
	\x0e	\x27	\x66	\x81
	\xea	\x06	\x27	\xb0
	\x37	\xcd	\x80	\x61
	\x61	\x61	\x61	\x61
	\x61	\x61	\x61	\x61
	\x61	\x61	\x61	\x61
	\x04	\x03	\x02	\x01
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2. Heuristic tools that check if at least some test before dangerous operation (like `strcpy`, `puts`, etc.) takes place
3. Dynamic bounds checking (with help of static analysis)
4. Bound checking insertion (complex)

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  - Optimizations
  - Further analysis
  - Bug hunting

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  - Call Strings
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  - Summary Based

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- Several basic approaches:
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    - Call Strings
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    - Summary Based
- Buffer overflow = third most dangerous code weakness.

Any questions?

Used/Additional Literature

AHO, A.; LAM, M.; SETHI, R.; et al.: Compilers: Principles, Techniques and Tools. Pearson Education, 2005, ISBN 978-0321486813.

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The MITRE Corporation.: Common Weakness Enumeration – CWE-120: Buffer Copy Without Checking Size of Input ('Classic Buffer Overflow'). [online], Last Updated 14.5.2012, [cit. 2012-11-30]. Available at: http://cwe.mitre.org/data/definitions/120.html.