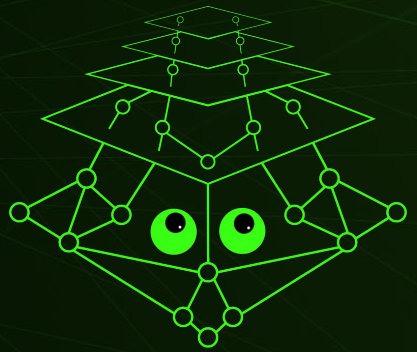
Workshop

Finding STRANGER THINGS in Code



JOERN

Suchakra Sharma
Staff Scientist, ShiftLeft Inc.

March 5, 2020
Pasadena, CA

SCaLE 18x

ShiftLeft

Let's Prep First

- *Clone Workshop Repo*
  - https://github.com/tuxology/joern-workshop
  - `apt install source-highlight graphviz unzip`
- *Download **joern-cli.zip** and extract it in the workshop directory*
  - https://github.com/ShiftLeftSecurity/joern/releases
  - `unzip joern-cli.zip`
- Download ***VLC v3.0.8*** source and extract in workshop directory
  - http://get.videolan.org/vlc/3.0.8/vlc-3.0.8.tar.xz
  - `tar -xvf vlc-3.0.8.tar.xz`

Suchakra Sharma

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PhD, École Polytechnique de Montréal

Loves systems, code analysis, performance analysis, hardware tracing, samosas and poutine!

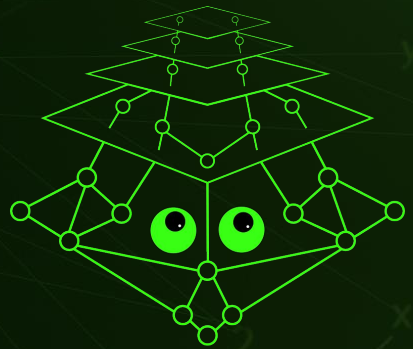

PepTalk

Why are you here?

- ***You want to,***
  - Hack and secure your applications
  - Learn how programming languages work
  - Hunt bugs and gain insights about your code
- ***Have questions like,***
  - What is static code analysis?
  - How do I do it interactively?
  - What is inside this mammoth code base?
  - What is even *code*? 😏

Pre-Workshop Poll

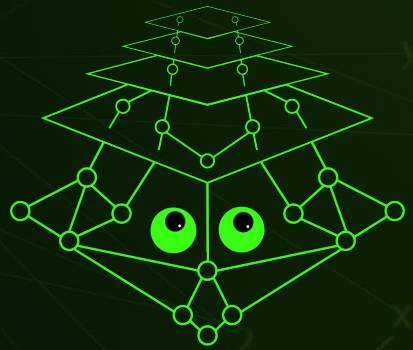
- ***I have used or know about***,
  - Interactive debuggers (GDB, rr)
  - SAST tools like Veracode/Coverity/FindSecBugs
  - Radare/PEDA/IDA Pro for security analysis
- ***I usually,***
  - Use Github to search through my code
  - Exclusively use an IDE/Editor to sift through my code
  - Grep through my source code looking for weird strings
  - Don’t care about code



JOERN

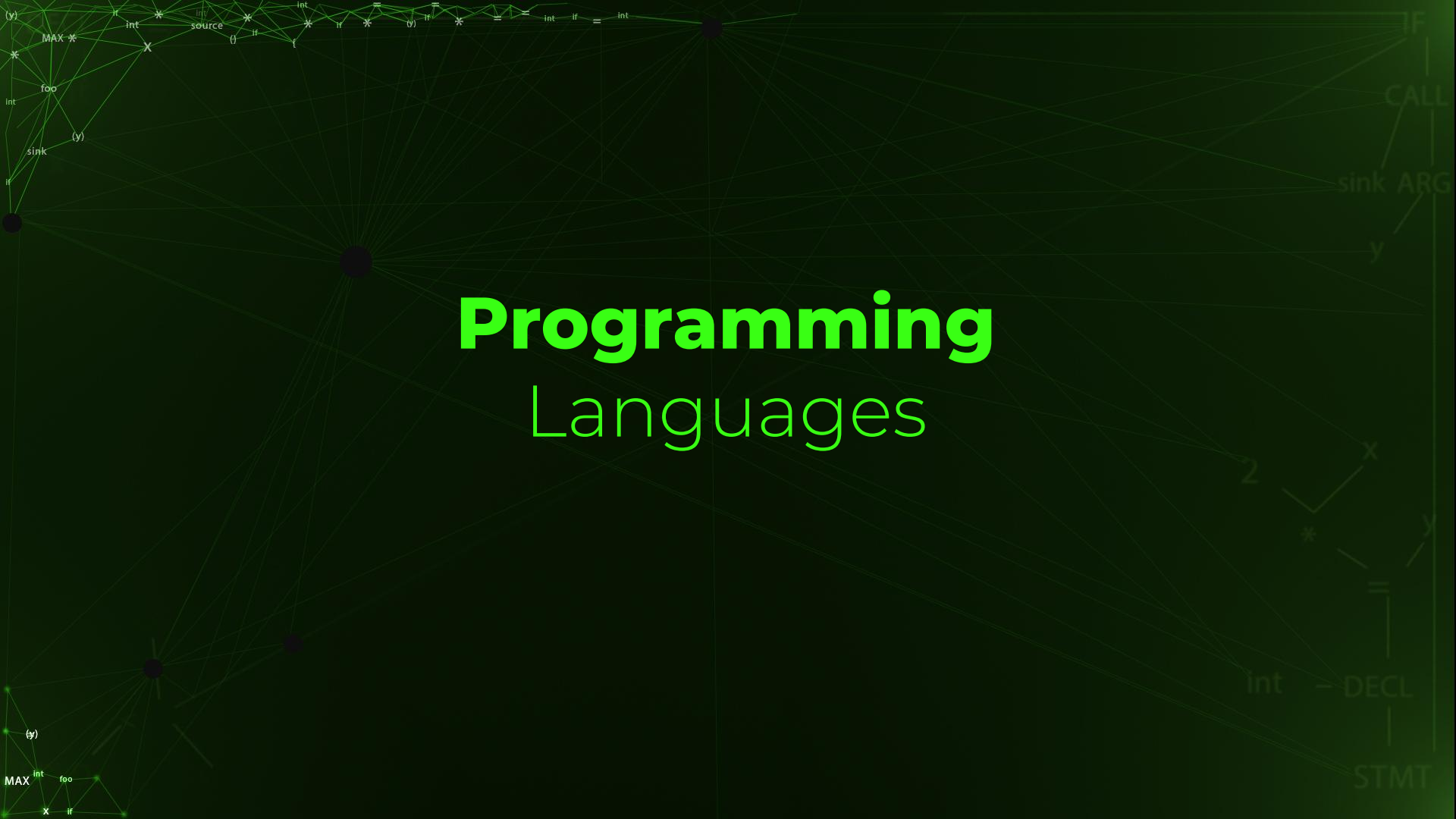
Interactive Code Analysis

> *“Each program is its own universe, and hacking is about exploring, documenting and exploiting its rules”*
>
> *~ Fabian*



JOERN

- Debugging goes hand in hand with running code
  - AddressSanitizer, ThreadSanitizer, profilers, linters
- Many tools run, and then give results but this approach flips the table - we use the tool to ask questions about the code
- It’s like play-pause debugging, but for static analysis
  - IDA Pro, Radare, PEDA etc.


Programming
Languages

What is even *code*?

```
int y = x + 50;
```

What is even *code*?

```
int y = x + 50;
```

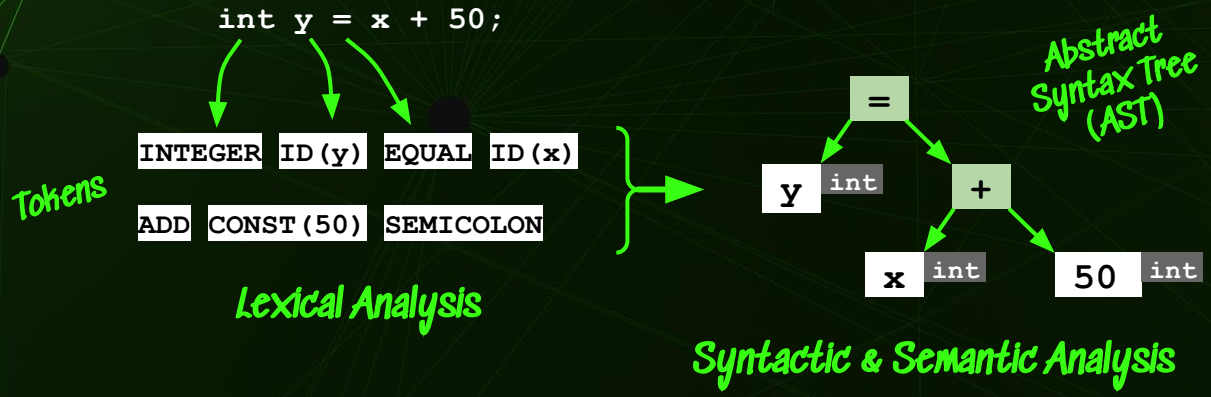
```
INTEGER  ID(y)  EQUAL  ID(x)

ADD  CONST(50)  SEMICOLON
```

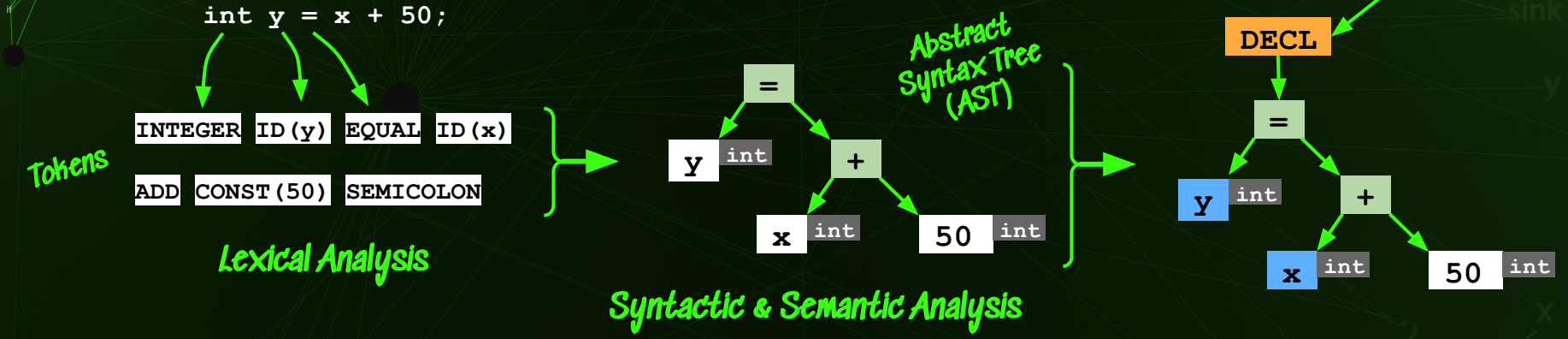
Tokens

Lexical Analysis

What is even *code*?



What is even *code*?



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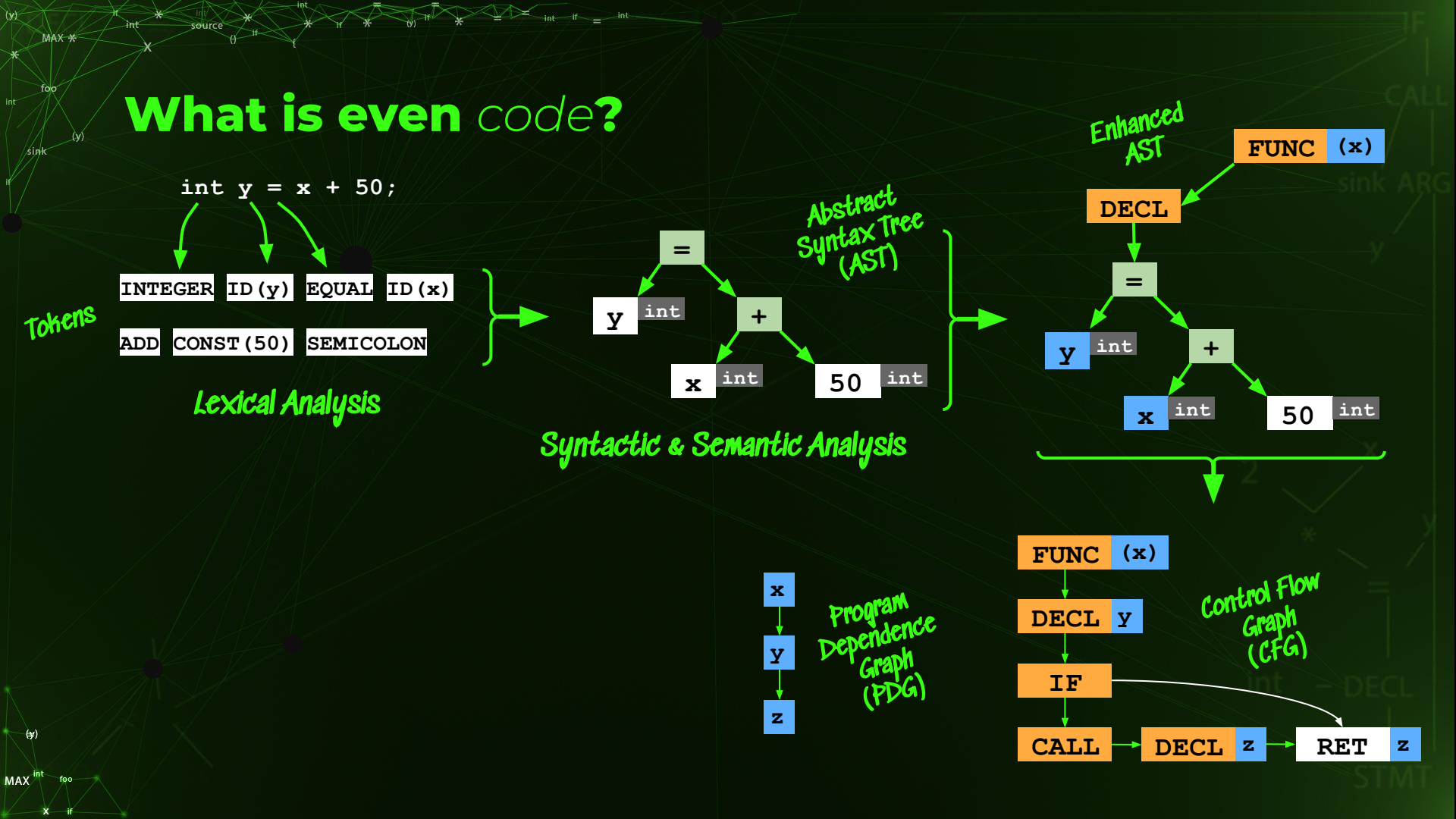
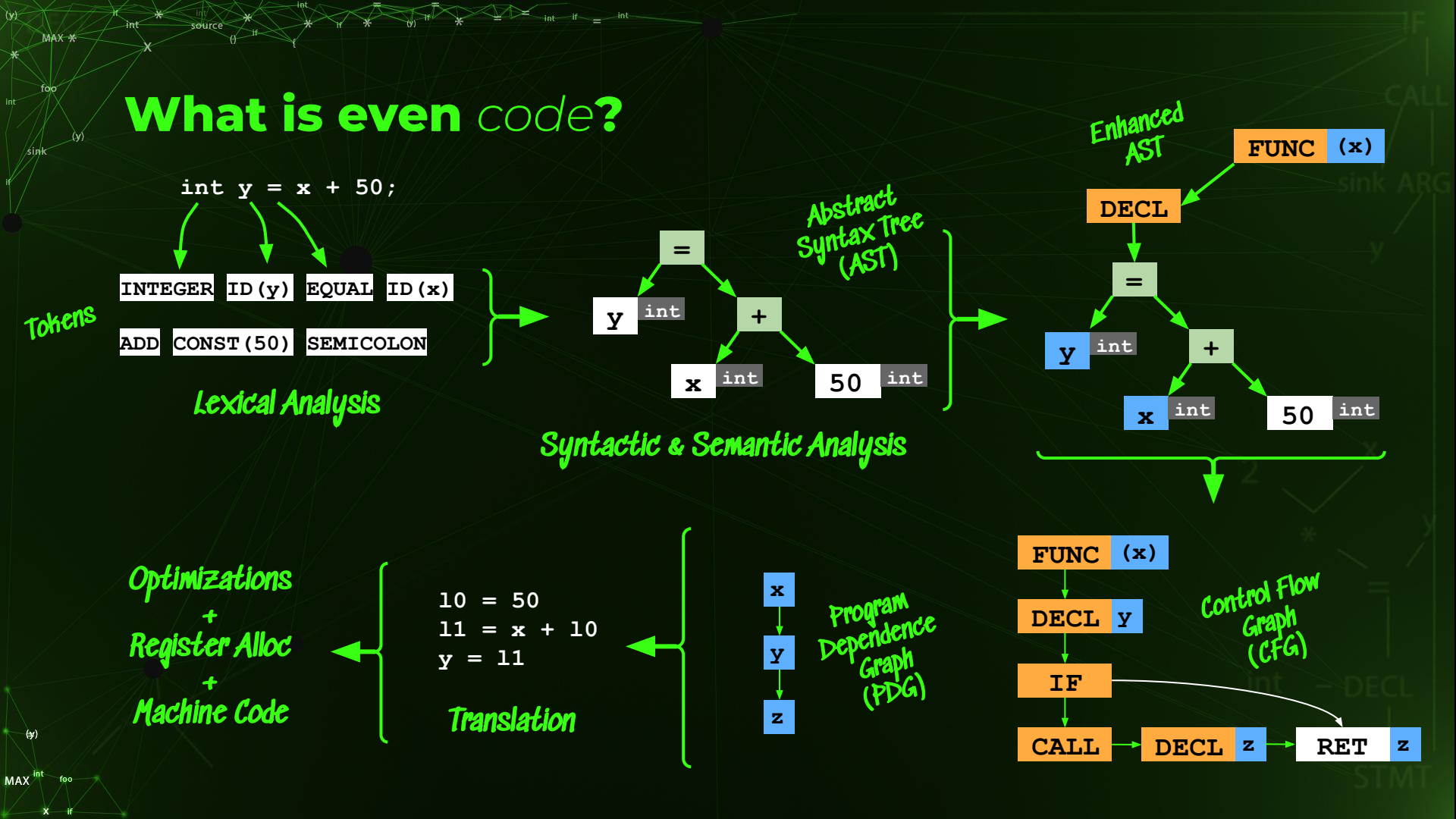


What is even *code*?



Building Blocks of Code

```
import org.springframework.web.bind.annotation.RestController;

@RestController
public class PatientController {

  private static Logger log =
          LoggerFactory.getLogger(PatientController.class);

  ...

  @RequestMapping(value = "/patients", method = RequestMethod.GET)
  public Iterable<Patient> getPatient(Int id) {
     Patient pat = patientRepository.findById(id);

     if (pat != null) {
          log.info("First Patient is {}", pat.toString());
     }

     return patientRepository.findAll();
}
```

Building Blocks of Code

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public class PatientController {

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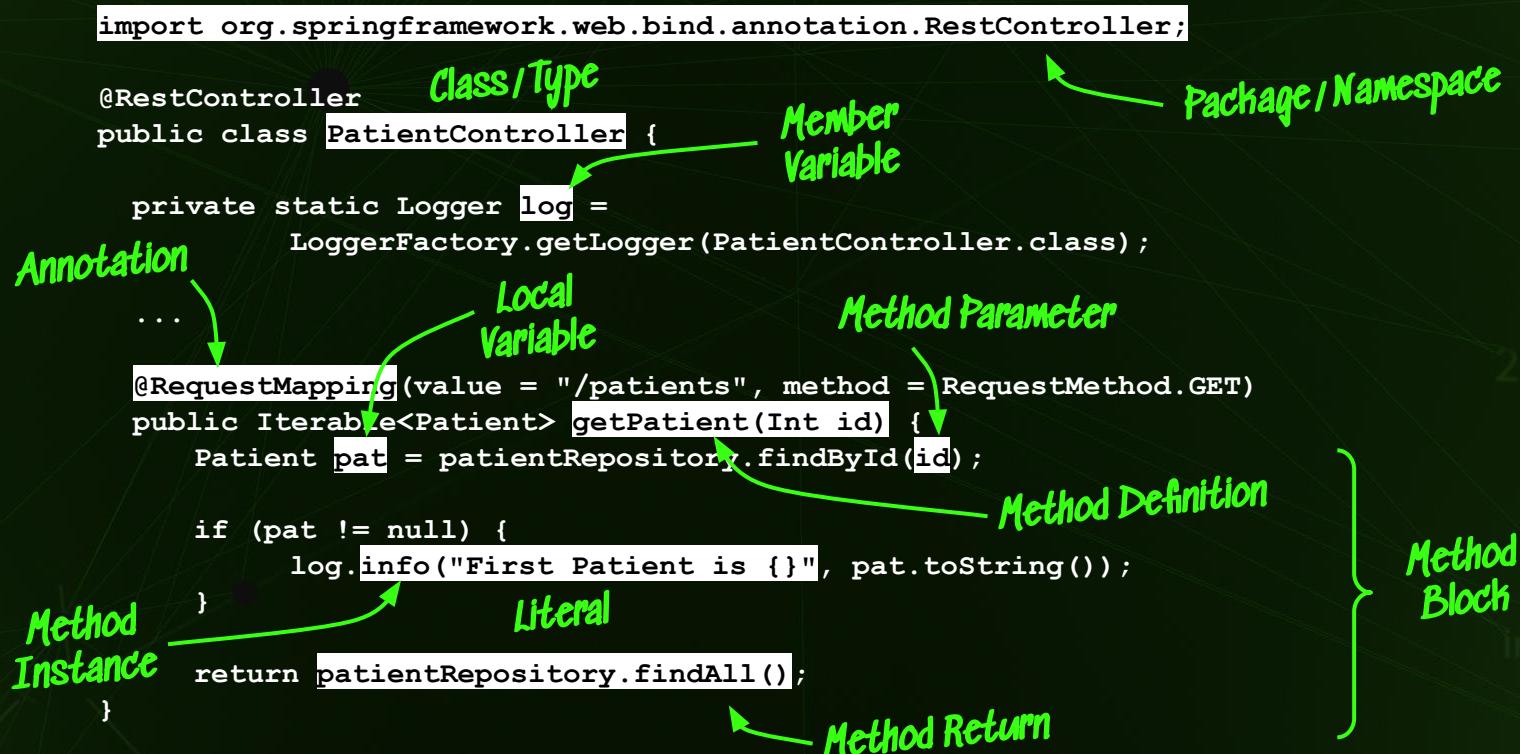
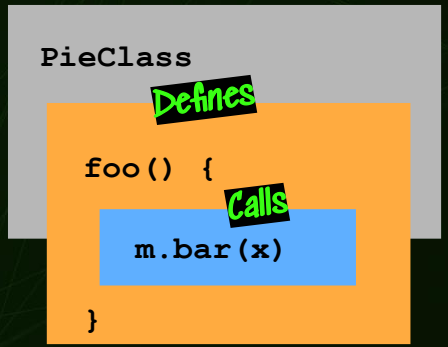
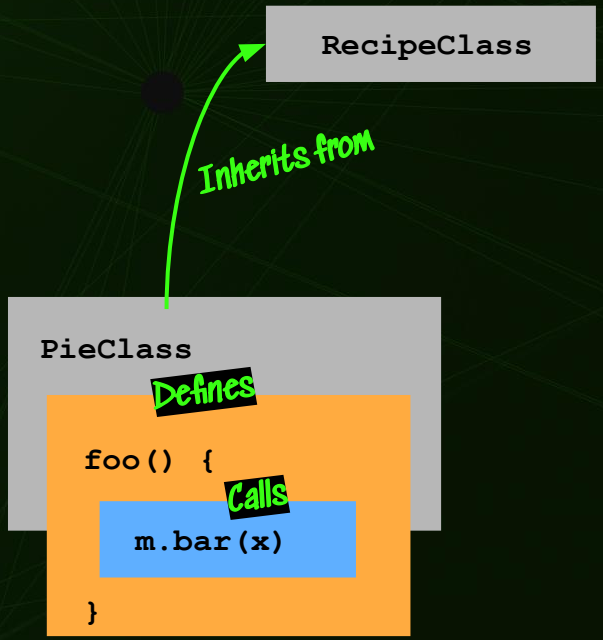
Building Blocks of Code



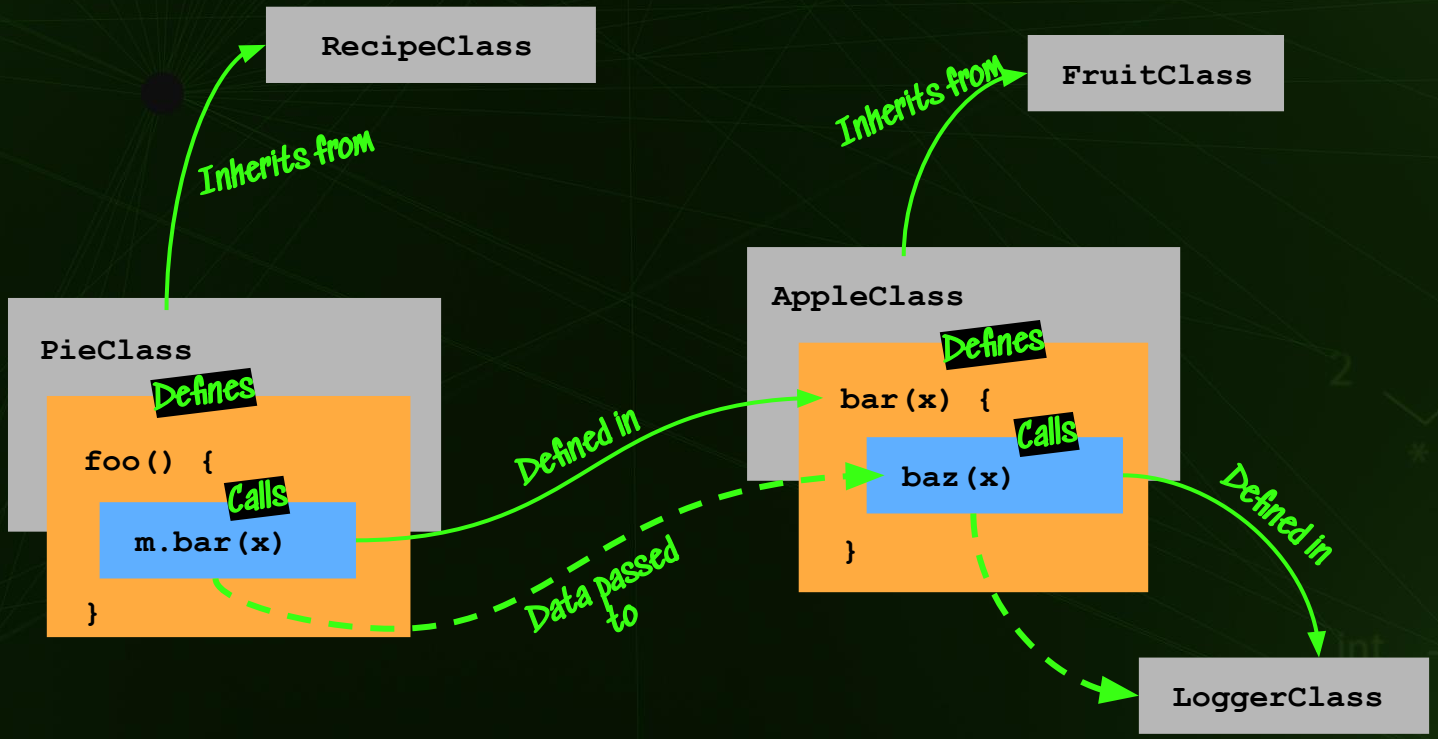
Building Blocks of Code



Building Blocks of Code

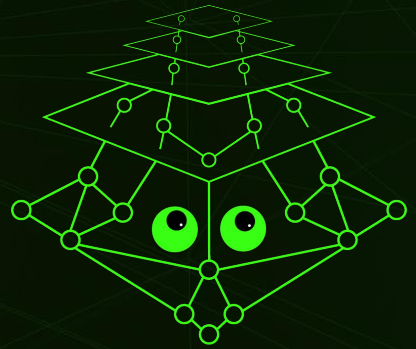


Building Blocks of Code



ALL THE CODE IS A GRAPH

If we think in graphs while coding, we should think in graphs while debugging

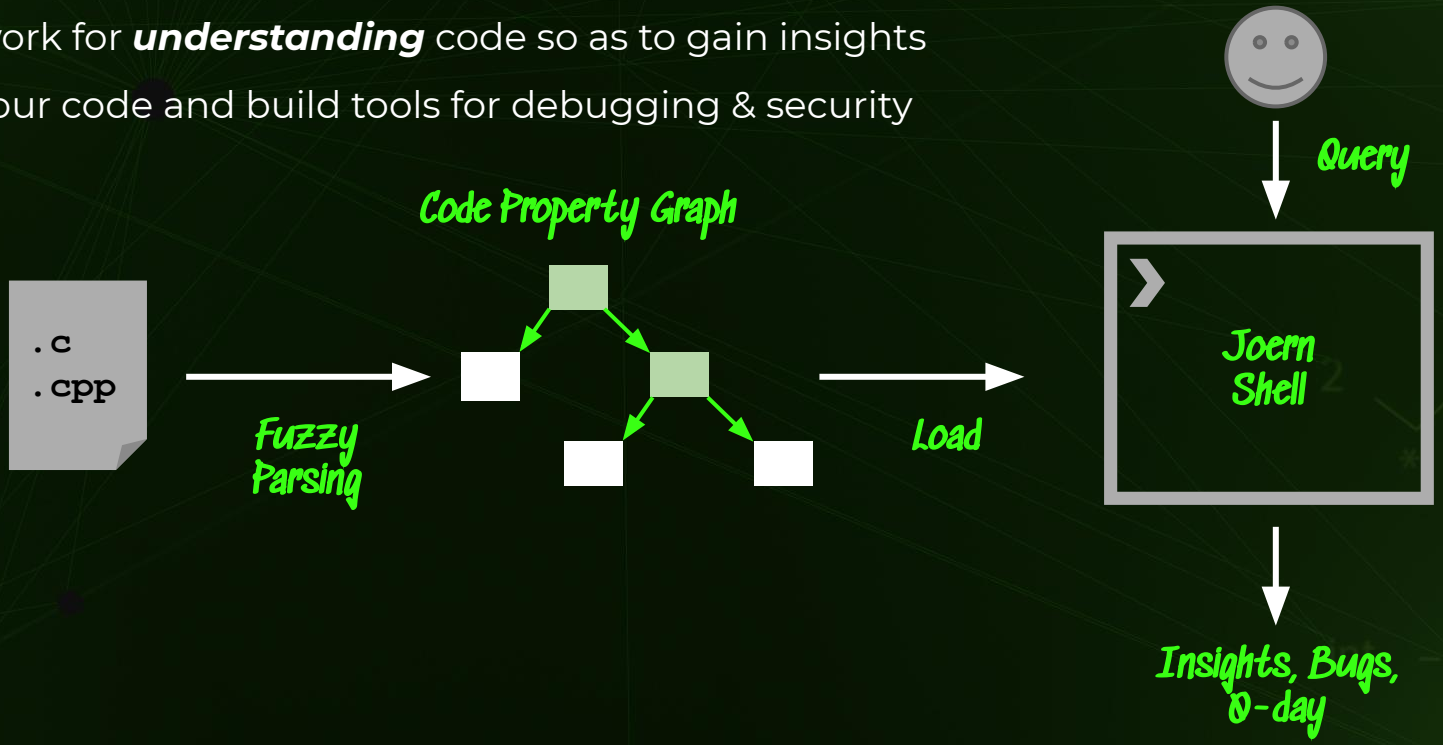


JOERN

[Yo! Urn]

What is Joern?

Framework for ***understanding*** code so as to gain insights about your code and build tools for debugging & security



Module 1

Code Surfin'

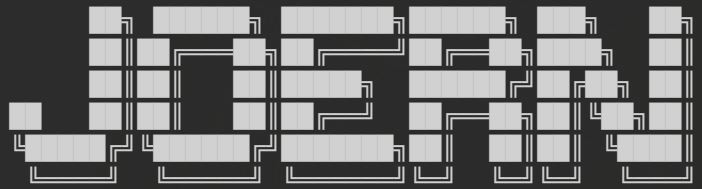
Module 1

1. Parsing and Generating a CPG (VLC v3.0.8)

suchakra@isengard: ~

suchakra@isengard: ~

```
$ wget https://github.com/ShiftLeftSecurity/joern/releases/latest/download/joern-cli.zip
$ unzip joern-cli; cd joern-cli
$ ./joern-parse ~/joern-workshop/vlc-3.0.8/
$ ./joern
```



```
Welcome to Ocular/Joern
joern> loadCpg("cpg.bin")
res0: Option[Cpg] = Some(io.shiftleft.codepropertygraph.Cpg@4f7a2262)
joern> cpg.<TAB>
```

Module 1

2. Basic Navigation - Methods

suchakra@isengard: ~

suchakra@isengard: ~

```
// List all methods that match `.*parse.*` to the shell
joern> cpg.method.name(".*parse.*").name.l

// Dump all methods that match `.*parse.*` to the shell (syntax-highlighted)
joern> cpg.method.name(".*parse.*").dump

// Create K-V pair of all methods that match `.*parse.*` and their code
joern> cpg.method.name(".*parse.*").map( m=> (m.name, m.start.dump)).l

// Dump all methods that match `.*parse.*` to file (no highlighting)
joern> cpg.method.name(".*parse.*").dumpRaw |> "/tmp/foo.c"

// View all methods that match `.*parse.*` in a pager (e.g., less)
joern> browse(cpg.method.name(".*parse.*").dump)
```

Module 1

2. Basic Navigation - Methods

suchakra@isengard: ~

suchakra@isengard: ~

```
// Dump dot representations of ASTs for all methods that
// match `parse` into file
joern> cpg.method.name("parse_public_key_packet").dot |> "/tmp/foo.dot"
```

Module 1

2. Basic Navigation - Methods

suchakra@isengard: ~

suchakra@isengard: ~

```
// Find all local variables defined in a method
joern> cpg.method.name("parse_public_key_packet").local.name.l

// Find which file and line number they are in
joern> cpg.method.name("parse_public_key_packet").location.map( x=> (x.lineNumber.get,
x.filename)).l

// Find the type of the first local variable defined in a method
joern> cpg.method.name("parse_public_key_packet").local.typ.name.l.head

// Find all outgoing calls (call-sites) in a method
joern> cpg.method.name("parse_public_key_packet").callOut.name.l

// Find which method calls a method
joern> cpg.method.name("parse_public_key_packet").caller.name.l
```

Module 1

3. Basic Navigation - Types and Filters

suchakra@isengard: ~

suchakra@isengard: ~

```
// List all local variables of type `vlc_.*`
joern> cpg.types.name("vlc_.*").localsOfType.name.l

// Find member variables of a struct
joern> cpg.types.name("vlc_log_t").map( x=> (x.name, x.start.member.name.l)).l

// Find local variables and filter them by their type
joern> cpg.local.filter(_.typ.name("vlc_log_t")).name.l

// Which method are they used in?
joern> cpg.local.filter(_.typ.name("vlc_log_t")).method.dump

// Get the filenames where these methods are
joern> cpg.local.filter(_.typ.name("vlc_log_t")).method.file.name.l
```

Module 1

4. Basic Insights - Overview

suchakra@isengard: ~

suchakra@isengard: ~

```
// Identify functions with more than 4 parameters
joern> cpg.method.where(_.parameter.size > 4).signature.l

// Identify functions with > 4 control structures (cyclomatic complexity)
joern> cpg.method.where(_.controlStructure.size > 4).name.l

// Identify functions with more than 500 lines of code
joern> cpg.method.where(_.numberOfLines >= 500).name.l

// Identify functions with multiple return statements
joern> cpg.method.where(_.ast.isReturn.l.size > 1).name.l
```

Module 1

4. Basic Insights - Overview

suchakra@isengard: ~

suchakra@isengard: ~

```
// Identify functions with more than 4 loops
joern> cpg.method.where(_.ast.isControlStructure.parserTypeName("(For|Do|While).*").size >
4).name.l

// Identify functions with nesting depth larger than 3
joern> cpg.method.where(_.depth(_.isControlStructure) > 3).name.l
```

Module 1

5. Basic Insights - Calls into libraries

suchakra@isengard: ~

suchakra@isengard: ~

```
// All names of external methods used by the program
joern> cpg.method.external.name.l.distinct.sorted

// All calls to functions that start with "str*"
joern> cpg.call("str.*").code.l

// All methods that call strcpy
joern> cpg.call("strcpy").method.name.l

// Looking into parameters: second argument to sprintf is NOT a literal
joern> cpg.call("sprintf").argument(2).filterNot(_.isLiteral).code.l

// Quickly see this method above
joern> cpg.call("sprintf").argument(2).filterNot(_.isLiteral).dump
```

Module 2

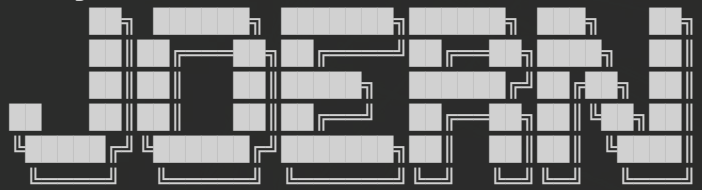
Memory Mémoire

Module 2

1. Generating CPG for `alloc_party.c`

suchakra@isengard: ~

```
joern> exit
$ ./joern-parse ~/joern-workshop/alloc_party --out alloc.bin
$ ./joern
```



```
Welcome to Ocular/Joern
joern> loadCpg("alloc.bin")
res0: Option[Cpg] = Some(io.shiftleft.codepropertygraph.Cpg@4f7a2262)
joern> cpg.<TAB>
```

Module 2

2. Memory Allocation Bugs - Zero Alloc/Overflow

suchakra@isengard: ~

suchakra@isengard: ~

```
/*
 * So we have a situation where the malloc's argument contains an arithmetic operation
 *
 * This can lead to two cases:
 *   1. Zero Allocation, if the operation makes the argument 0 (we get a NULL ptr)
 *   2. Overflow, if the computed allocation is smaller and we use memcpy() eventually
 */

void *alloc_havoc(int y) {
  int z = 10;
  void *x = malloc(y * z);
  return x;
}
```

Module 2

2. Memory Allocation Bugs - Zero Alloc/Overflow

suchakra@isengard: ~

suchakra@isengard: ~

```
// The location where malloc has an arithmetic operation
joern> cpg.call("malloc").filter(_.argument(1).arithmetics).code.l

// Identify if there is a flow from a given method's param to a malloc()'s param with an
// arithmetic operation
joern> var source = cpg.method.name(".*alloc.*").parameter
joern> var sink = cpg.call("malloc").filter(_.argument(1).arithmetics).argument
joern> sink.reachableByFlows(source).p

// Ref: https://suchakra.wordpress.com/2019/10/07/zero-day-snafus-hunting-memory-allocation-bugs/
```

Module 2

2. Memory Allocation Bugs - Double Free

suchakra@isengard: ~

suchakra@isengard: ~

```
// Find how many data flows are there starting from the same malloc() call-site
// to parameters of all free() call-sites. If more than one, we can inspect them for double free

joern> var source = cpg.call(".*alloc.*")
joern> var sink = cpg.call("free").argument
joern> sink.reachableByFlows(source).p
```

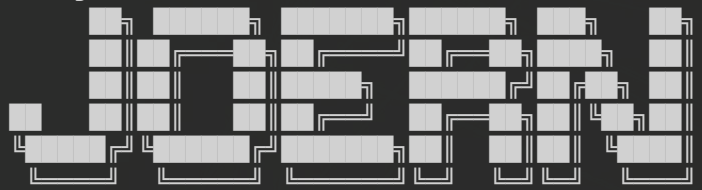
Module 2

3. Back to the VLC CPG

suchakra@isengard: ~

suchakra@isengard: ~

```
joern> exit
$ ./joern
```



```
Welcome to Ocular/Joern
joern> loadCpg("vlc.bin")
res0: Option[Cpg] = Some(io.shiftleft.codepropertygraph.Cpg@4f7a2262)
```

Module 2

3. Memory Allocation Bugs - Buffer Overflow

suchakra@isengard: ~

suchakra@isengard: ~

```
/**
  * Find calls to malloc where the first argument contains an arithmetic expression,
  * the allocated buffer flows into memcpy as the first argument, and the third
  * argument of that memcpy is unequal to the first argument of malloc. This is
  * an adaption of the old-joern query first shown at 31C3 that found a
  * buffer overflow in VLC's MP4 demuxer (CVE-2014-9626).
  **/

  val src = cpg.call("malloc").filter(_.argument(1).arithmetics).l

  cpg.call("memcpy").whereNonEmpty { call => call.argument(1)
        .reachableBy(src.start)
        .filterNot(_.argument(1)
        .codeExact(call.argument(3).code))
  }.code.l
```

Module 3

Scripting Away to Glory

Module 3

1. Scripting - Buffer Overflow

suchakra@isengard: ~

suchakra@isengard: ~

```
/*
 * We can wrap the previous query as a function that we can use internally
 * anytime we like!
 */

joern> def buffer_overflows(cpg : io.shiftleft.codepropertygraph.Cpg) = {
         val src = cpg.call("malloc").filter(_.argument(1).arithmetics).l

         cpg.call("memcpy").whereNonEmpty { call => call.argument(1)
               .reachableBy(src.start)
               .filterNot(_.argument(1)
               .codeExact(call.argument(3).code))
         }
       }

defined function buffer_overflows
joern> buffer_overlows(cpg).code.l // run the custom script (try .location.l as wel)
```

Module 3

`p_block->i_buffer == MAX_UINT64` causes an overflow!

suchakra@isengard: ~

suchakra@isengard: ~

```
joern> buffer_overlows(cpg).filter(_.method.name(".*ParseT.*")).l.start.dump
res57: List[String] = List(
  """static subpicture_t *ParseText( decoder_t *p_dec, block_t *p_block )
{
    decoder_sys_t *p_sys = p_dec->p_sys;
    subpicture_t *p_spu = NULL;
    if( p_block->i_flags & BLOCK_FLAG_CORRUPTED )
        return NULL;
      ...
    /* Should be resiliant against bad subtitles */
    if( p_sys->iconv_handle == (vlc_iconv_t)-1 ||  p_sys->b_autodetect_utf8 )
    {
        psz_subtitle = malloc( p_block->i_buffer + 1 );
        if( psz_subtitle == NULL )
            return NULL;
        memcpy( psz_subtitle, p_block->p_buffer, p_block->i_buffer ); /* <=== */
        psz_subtitle[p_block->i_buffer] = '\0';
    }
```

Module 3

2. Scripting - Build Your Own Joern Scripts

suchakra@isengard: ~

suchakra@isengard: ~

```
// Save the following in as heap.sc

    def buffer_overflows(cpg : io.shiftleft.codepropertygraph.Cpg) = {
          val src = cpg.call("malloc").filter(_.argument(1).arithmetics).l

          cpg.call("memcpy").whereNonEmpty { call => call.argument(1)
                .reachableBy(src.start)
                .filterNot(_.argument(1)
                .codeExact(call.argument(3).code))
           }
         }

// Import and execute from Joern
joern> import $file.^.heap
joern> heap.buffer_overflows(cpg).code.l
```

Module 3

3. Scripting - DIY Tooling!

suchakra@isengard: ~

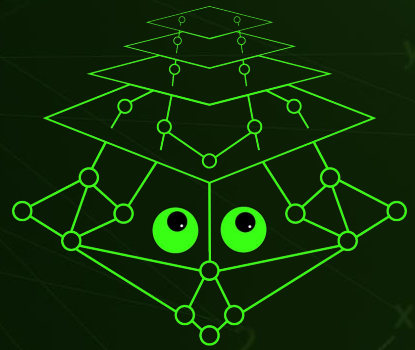
suchakra@isengard: ~

```
// Save the following file as buffer_overflow.sc

@main def execute(payload: String) = {
    loadCpg(payload);
    val src = cpg.call("malloc").filter(_.argument(1).arithmetics).l

    cpg.call("memcpy").whereNonEmpty { call => call.argument(1)
          .reachableBy(src.start)
          .filterNot(_.argument(1)
          .codeExact(call.argument(3).code))
    }.code.l
}

// Run externally as your own tool!
$ ./joern --script buffer_overflow.sc --params payload=vlc.bin
```


EOF

Acknowledgements

- Fabian Yamaguchi, friend and inventor of CPG and Joern
  - Talk: https://fabs.codeminers.org/talk/2019-huawei/
- Joern Community
  - Markus, Niko, Michael, Chetan
- Jöern (@joernchen) - yes, there is a real person for which the project was named



JOERN

Thanks Folks

Community: https://gitter.im/joern-code-analyzer/community
Website: http://joern.io

Workshop Resources: https://github.com/tuxology/joern-workshop

Twitter: @tuxology
Mail: mail@suchakra.in