COMS E6998-9:

Software Security and Exploitation

Lecture 7: Vulnerabilities Cont. +

Data Security and Cryptography

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More Vulnerabilities

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XSS

- Cross site scripting (XSS) vulnerabilities come from user data being displayed on web pages
- If that data is malicious, attackers can gain access to account information, data, and functionality accessible by the victim
- Can be one of the easiest attacks to carry out
- Fortunately there are many anti-XSS libraries available (depending on your platform) that you can use to sanitize data

Command Injection

- Command injection is not limited to SQL or JavaScript
- Any time user data is mixed with executable code there is the potential of command injection
- You should never mix code with data given the potential for manipulation

Beware 2nd Order Attacks

- 2nd order attacks occur when malicious data passes through initial defenses, is stored, and then accessed later by a vulnerable function
- Particularly dangerous because they are almost always missed by security testing
- The threat of 2nd order attacks builds a strong case for properly sanitizing data that is to be stored

Canonicalization Problems

- Canonicalization is the process of converting data that has multiple representations to a single standard "canonical" form
- The problem is that there are alternate ways to represent things:
  - Files, URLs, IP addresses, Paths, etc.
- Sometimes there are strange representations you don't expect…

Canonicalization Problems

- Windows example:

  “securecoding.txt” ≠ “secure~1.txt”
- BUT…the OS can treat all of the following as the same:
  - securecoding.txt
  - secure~1.txt
  - securecoding.txt::$DATA
  - securecoding.txt.
  - Many more!
- Attackers can leverage this fact to create inputs that sneak past filters yet force the application to access an unintended resource

Unicode Threats

- When dealing with Unicode strings, string comparison failure can cause unexpected results
- Always consider:
  - When evaluating size, what's being measured
  - Some string comparisons are byte-wise

Data Security and Cryptography

Developer’s Cryptography Primer

- Cryptography is good at protecting data at rest or in transit. It does little for data in use and protects against only a very narrow set of threats
- Symmetric Cryptography - a single shared secret is used to encrypt and decrypt

  Methods: 3DES, AES, etc.
- Asymmetric Cryptography – a different secret is used to encrypt and decrypt

  Methods: RSA, etc.

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Symmetric vs. Asymmetric Cryptography

Symmetric Key	Asymmetric Key
Requires a shared secret to be maintained	There are two keys used
Computationally cheap	Computationally expensive
Difficulties in transporting the key securely (key exchange problems)	Public Key Infrastructure (PKI) can be used to distribute keys via a trusted 3rd party
Used widely because of computational ease	Typically used to verify authenticity (through an encrypted hash) or to exchange a private key

On the Replace-ability of Algorithms

- As computational power increases, the effectiveness of some cryptographic implementations decreases
- Many companies have switched from DES to 3DES to AES
- This speaks to the fact that we need to write code with the foresight that the cryptographic implementation used may need to change
- One of the biggest reasons that encryption breaks down is through improper implementation: don't code your own implementation or create your own algorithm

Practical key management

- Poor key management is one of the biggest weaknesses in a cryptographic implementation
- Top things to remember:
  - A key stored in source code can be found through simple reverse engineering
  - A key stored in a configuration file can be found even more simply
  - A key stored in your application can be replaced (if the attacker has access to the application)

Hashes

- A *cryptographic hash function* is a reproducible method of turning a large *message* into a small digest (*hash*) of that message
- Hashes are good to help verify the integrity of data
- It should have the following properties:
  – One-way: It should be hard to find a message that yields a given digest (basically we shouldn't be able to reconstruct the message from the digest)
  – No collisions: It should be difficult to find two messages that produce the same hash
  – No iterative refinement: A small change in the message should result in an unpredictable change in the hash

Hashes

- Popular cryptographic hashing algorithms are MD5 and SHA1

  This text is going to change slightly

  SHA1 Hash: 2ea1565ca629e2c1562d9a7aa5d1b15dbc2604e7

  MD5 Hash: 700a21e5bceef03b1ada0b59bf98705c

  This text is going to change slightli

  SHA1 Hash: 5e6a81193372ac6b2450d3a17156079c264dfbea

  MD5 Hash: b594837fd1c1dd53c2db5c34ee52b7c5

- Hashes are often encrypted using asymmetric cryptography to create *digital signatures* that can verify a message's authenticity and integrity

Data Integrity

- Data integrity means that data has not been tampered with and is complete
- A common means of ensuring data integrity is to use digital signatures (encrypted hash values)
- Remember that if you store a hash or a key in your code that it can be both reverse engineered out and replaced

Memory protection - Dangers

- Secrets left in memory are risky for the following reasons:
  - A crash could cause memory data to be dumped to disk
  - Data may remain in memory long after it is addressable
  - Memory locations can be reclaimed by the JVM and thus be used in ways never expected (such as to pad packets)

Memory protection – Solutions

- Overwrite sensitive data before freeing or returning from a function
- Consider in-memory encryption
  - (CryptProtectMemory() in Windows for example)
- Lock sensitive data so that it cannot be paged to disk (mlock(), mlockall(), and VirtualLock())
  - Warning: This can have sever performance impact

Random number generation

- Don't use RAND – it has poor entropy and predictability
- Use a cryptographically secure pseudo-random number generator (CSPRNG)
- These are available in crypto libraries such as OpenSSL
- Consider the consequences of a user being able to predict random number values:
  - Cookies; encryption keys; filenames; behavior; etc.

Introduction to secure audit and log

- Tips on Logs:
  - Should only be writable by administrator/root and the application that is logging
  - Should be considered highly sensitive
  - You should ensure that attackers cannot fill logs by checking on length and taking standard precautions (such as a new log file every day)
  - Remember that sometimes regulations dictate some information that must be logged and some information that cannot be logged
  - Failed password attempts can hold sensitive data!
  - Consider using hashed if the only purpose of a piece of information is confirmation

Reverse Engineering and Avoiding Security by Obscurity

- You must assume that if users have your binaries then they have your source code
- The compiler is not an encryption tool
  - Any encryption keys can be easily located using an entropy scanner
- Tools such as IDA Pro, JAD, etc. make decompilation incredibly simple
- Commercial solutions to obfuscation exist but they serve to further delay reverse engineering, not prevent it (code eventually must be decrypted to run)

Security Testing Part 1: Fuzzing

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Introduction to Fuzzing

- What is fuzz testing (or "fuzzing")? Answer: Data corruption, plain and simple
- Fuzzing catches the cases you wouldn't think about…weird input, corner and fringe cases, cases that you may not expect to be bug revealing
- Tend to find: Buffer Overflows, Format String issues, traversal problems, and many others --- it all depends on the symptoms you look for
- Great because its automated
- A few things to define up front
  - Which interfaces does your application have?
  - What protocol/format/etc. is used?
  - What to define as a symptom of failure? (needed for automation --- more on this later)

Benefits of Fuzzing

- Highly automatable
- Finds vulnerabilities that wouldn't normally be detected during functional testing
- Inexpensive…free tools, low cost tools, or grow your own
- Can unearth some of the most critical vulnerabilities in software
- Gives a good sense of how robust an application is

What can be fuzzed?

- Anything that accepts input:
  - APIs
  - File parsers
  - Network protocols
  - GUIs
  - CLIs
  - Web services calls
  - URLs
  - Script

Data Corruption

- Long strings
- Special characters (general strings)
  - %s, /n, ‘, AUX, “../..”, …
  - Canonicalized forms of these can also be cool!
- Special values (numeric types)
  - 127, 0, -128, 32756, …
  - Boundary values and boundary values + 1 have been particularly interesting
- Other variable types and interesting strings
  - domain names, company names, …
- Other techniques: Flipping bits, swapping data, removing delimiters, incrementing values, …

Delivering the data to the application

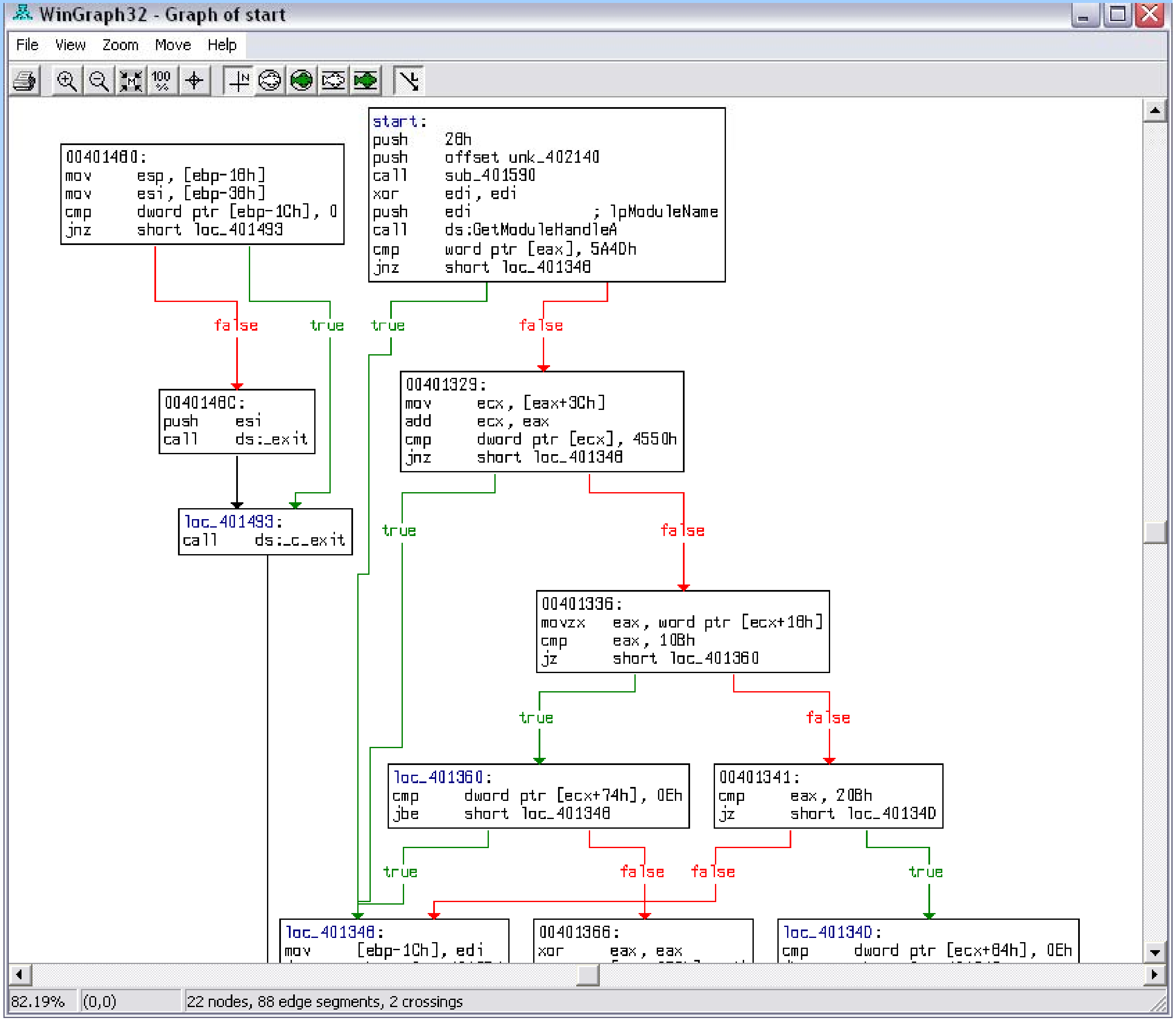
- Fuzzers need to create a container to deliver data
- May have to do things like:
  - Recalculate checksums
  - Add special identifiers
  - Mark certain sections to NOT corrupt (header tags, etc)
  - Encode your corrupted data (Base64, etc)
  - Encrypt your data (best in this case to corrupt BEFORE data hits encryption routines ((unless you're testing the parser)))
  - Create/Maintain containers (SOAP, HTTP, etc.)
  - Maintain type (for API parameters for example)

Types of Fuzzing

- Random (dumb)
  - Inserts random characters and strings
  - Not aware of much … may require a wrapper to be effective (eg SOAP, TCP/IP, file header,)
- Context-Aware
  - Has some notion of format and type (XML, APIs, etc.)
  - May use a bounded set of “random” data (integers, script tags, …)
- Adaptive
  - Changes the next corruption data based on execution
  - May be used to “cover” more of the application

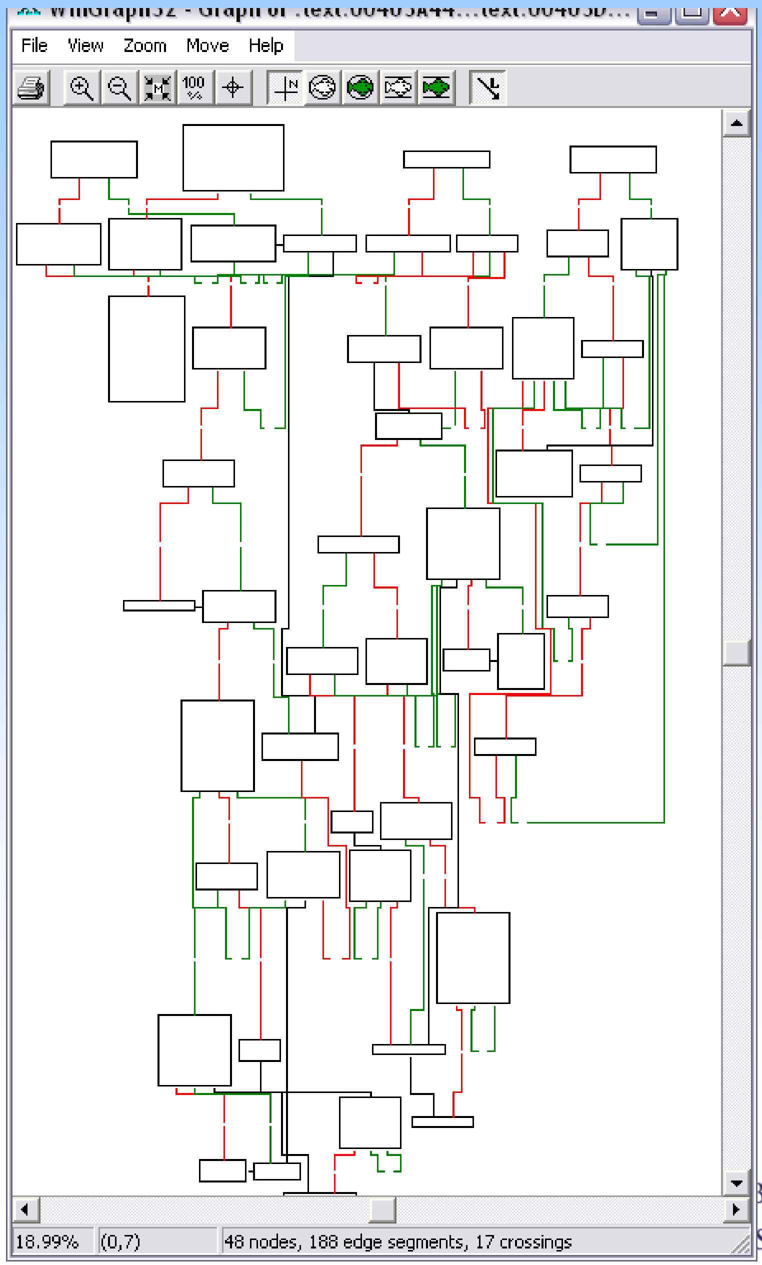
Illustrating the difference…Random

Pure random fuzzing may only test initial routines and not pass a formatting / protocol check by the application



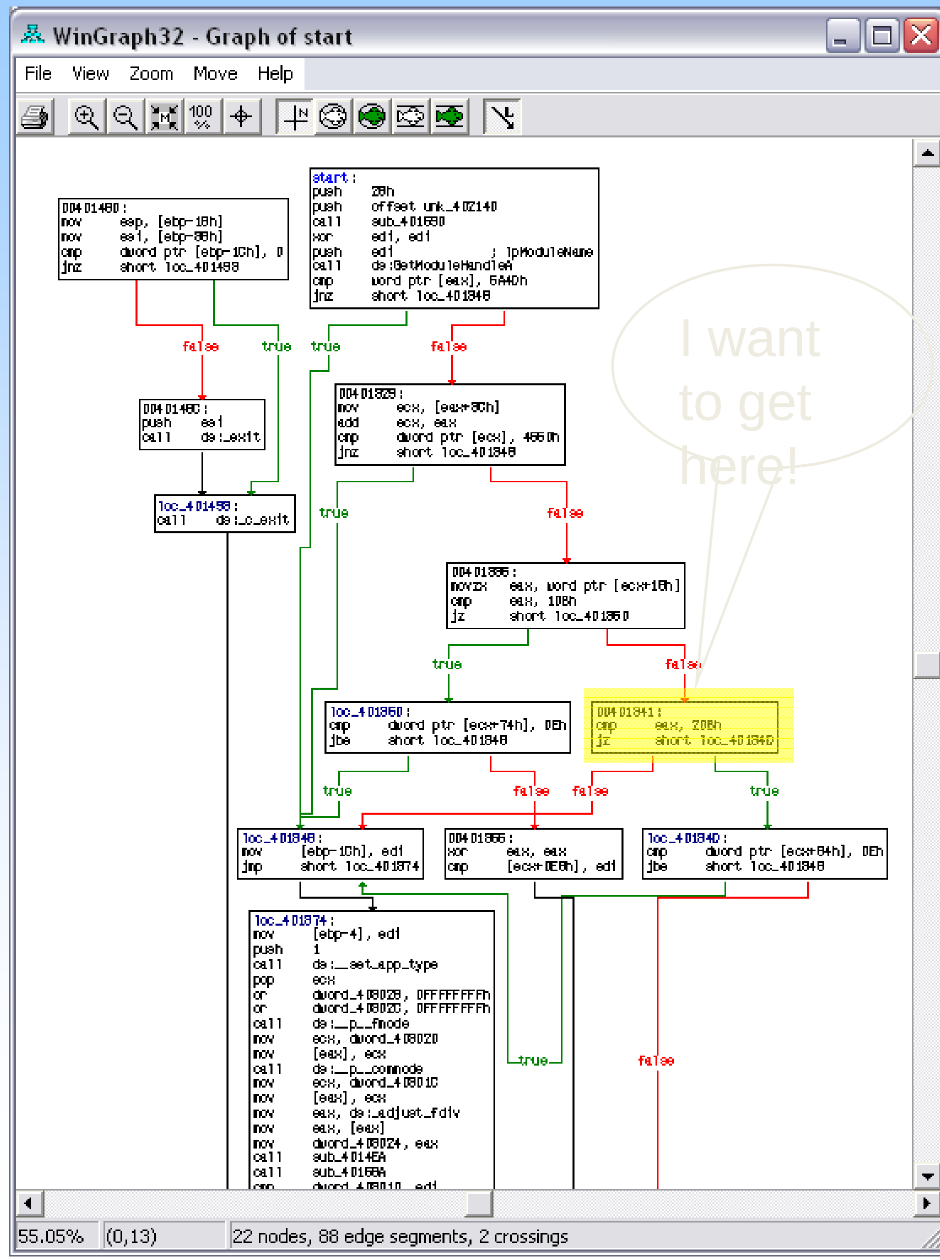
Illustrating the difference…Context-Aware

- Context-Aware testing may be necessary to get deeper into the application
- May need to bypass things like checksums, etc.
- May also included wrappers for protocols, formats, SOAP, web services, RPC, …, you name it!
- Likely to get more “coverage” of the application binary



Illustrating the difference…Adaptive

- Adaptive fuzzing uses feedback from the application or the debugger to modify the data that's sent.
- Can be used to get in-depth coverage on a binary
- Will adapt the data to get through branching "gates"
- Can find some really interesting vulnerabilities…especially combined with a binary scanner (like the BugScam IDC package)



A Word on Oracles

or·a·cle - Function: *noun* Etymology: *from Latin oraculum, from orare to speak*

a : person giving wise or authoritative decisions or opinions

b : an authoritative or wise expression or answer

- In testing, an "oracle" is something that gives you the right answer
- For fuzzing, we can only identify problems if an output is different than what we expected and we can compare the two (i.e. given by the oracle)
- For example, how would you automate the testing of a scientific calculator?

Things to look for (oracle)

- (EASY) Exceptions (first or second chances, read/write AV, …)
  - Tools: Debugging APIs
- (MEDIUM) Resource consumption (memory, disk, network, CPU)
  - Tools: Debugging APIs, Resource Monitors, Memory leak detectors
- (MEDIUM) Sandbox escape (folders, IP address ranges, APIs, registry, …)
  - Tools: Holodeck/HEAT APIs, Detours, FileMon, RegMon, …
- (ADVANCED) Binary/Data coverage or pattern changes

Stopping Criteria

- The decision that you've done "enough" fuzzing is really based on internal quality tolerance --- BUT --- in many cases it makes sense to continue fuzzing even after product release.
- There aren't great answers here but here are some criteria:
  - Business tells you to ship the product - even then it may make sense to fuzz till EOL
  - Binary coverage (we've touched x% of the reachable code through fuzzed inputs)
  - No differential coverage (only already-traversed paths get explored)
  - X number of "clean" runs

Challenges / Future of Fuzzing

- Metrics!
- Distributed fuzzing (divide and conquer)
- "Oracling" agents on server (used by some folks now)
- Good tools designed for fuzzing in a broader environment
- Knowledge sharing on fuzzing

Summary

- Fuzzing is interesting but it should only be part of an overall security strategy
- If there is poor coverage as you fuzz, its likely that the application may be rejecting large chunks of data because it's malformed – fuzz more granularly
- Fuzzing has already made its way into web application testing tools – expect broader tool support to exist