

Session 09  
Code Analysis

Security of Information Systems (SIS)

Computer Science and Engineering Department

December 9, 2020

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Ways of Securing Software

- ▶ secure by construction: prevent existence of bugs/vulnerabilities
- ▶ secure environment: prevent exploitation of bugs/vulnerabilities
- ▶ isolated environment: damage control

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Secure by Construction

- ▶ providing it as secure (build from specs)
- ▶ building it secure
- ▶ secure before shipping

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Secure by Construction (2)

- ▶ formal verification, provably secure
- ▶ programming language features
- ▶ programming practices
- ▶ defensive programming
- ▶ software development process
- ▶ code review
- ▶ code auditing
- ▶ testing
- ▶ fuzzing, symbolic execution

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## Common Practices/Principles

- ▶ keep it simple: small footprint, few dependencies, no fancy hacks
- ▶ input validation
- ▶ added care when dealing with buffers and strings
- ▶ use linters and static checkers
- ▶ make code readable, document while writing
- ▶ simple and intuitive interfaces
- ▶ mindset: assume the worse
- ▶ do unit tests

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## Program Analysis

- ▶ focus on applications (i.e. programs) not systems
- ▶ analyze program behavior
- ▶ performance
  - ▶ profiling
  - ▶ reduced resource usage
  - ▶ reduced overhead
- ▶ correctness
  - ▶ debugging
  - ▶ security
  - ▶ robustness
- ▶ no side channel focus

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## Ways of Doing Program Analysis

- ▶ control flow analysis: reachability
- ▶ data flow analysis: propagation

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## Types of Program Analysis

- ▶ static analysis: no running of program
- ▶ dynamic analysis: running the program
- ▶ source code analysis: source code is available, use it
- ▶ binary analysis: work on executables and binary files, source code may be unavailable

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## Static Analysis

- ▶ don't run the program
- ▶ go through its source/binary code
- ▶ control flow and data flow analysis

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## Dynamic Analysis

- ▶ monitor process
- ▶ usually involves instrumentation
- ▶ valgrind, profilers, Pin  
(<https://software.intel.com/en-us/articles/pin-a-dynamic-binary-instrumentation-tool>)

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## Source Code Analysis

- ▶ automated, semi-automated, manual
- ▶ manual: code auditing
- ▶ programming defects, API misuse, lack of compliance, correctness
- ▶ software/code interpretation, pattern matching
- ▶ software formal verification

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## Binary Analysis

- ▶ reverse engineering
- ▶ binary debugging
- ▶ disassembling, forensics

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## Terms

- ▶ program comprehension: understand source code
- ▶ code review: fix mistakes, improve code quality and programming practices
- ▶ code auditing: comprehensive analysis with intent of discovering bugs
- ▶ static analysis: automated action performed

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## Static Analysis

- ▶ analyze computer programs without executing them
- ▶ usually performed on source code
- ▶ automated process

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## Tools of the Trade

- ▶ editors/reading tools
- ▶ pattern matching tools
- ▶ static analyzers
- ▶ pen & pad

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## Tools of the Trade (2)

- ▶ open source
  - ▶ Sonar: <http://www.sonarsource.org/> (Java)
  - ▶ Flawfinder: <https://dwheeler.com/flawfinder/> (C/C++)
  - ▶ RATS
  - ▶ Clang Static Analyzer: <http://clang-analyzer.llvm.org/>
  - ▶ Splint: <http://splint.org/> (C) – no longer developed
  - ▶ cppcheck: <http://cppcheck.sourceforge.net/> (C, C++) – plugins for IDEs
- ▶ proprietary
  - ▶ Coverity SAVE: <http://www.coverity.com/products/coverity-save.html>
  - ▶ Klocwork Insight: <http://www.klocwork.com/products/insight/> (C, C++, Java, C#)
  - ▶ CodeSonar: <http://www.grammatech.com/codesonar>
  - ▶ Semmlle: <http://semmlle.com/solutions/>
  - ▶ HP Fortify

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## Binary Static Analysis

- ▶ requires reverse engineering
- ▶ focused on discovering bugs and creating exploitation PoCs form them to be fixed
- ▶ basic tools: disassemblers, symbol mappers, decompilers
- ▶ automated tools: Veracode, CodeSonar, BitBlaze
- ▶ security analysts, enhancing proprietary solutions

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## Code Auditing

- ▶ browse source code
- ▶ look for security breaches and possible bugs
- ▶ tools for static code analysis
- ▶ in-depth audit to be done by the developer

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## Black Box Approach

- ▶ non-open-source code
- ▶ understand protocol or user input format
- ▶ provide "bad" input and test possible violations
- ▶ reverse engineering
- ▶ fuzzing

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## White Box Approach

- ▶ the "real stuff" – actual code auditing, highlight input processing
- ▶ top-to-bottom: start from main, go down functions
- ▶ bottom-to-top: find all places of external input, system input and start from there

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## Tools to be Employed

- ▶ static analyzers (cppcheck, Clang Static Analyzer, Coverity)
- ▶ IDA for binary static analysis
- ▶ ctags, cscope, source nav for source code navigation
- ▶ debuggers for runtime analysis
- ▶ valgrind, Rational Purify for dynamic analysis

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## Code Auditor Requirements

- ▶ know API, OS and machine (background knowledge)
- ▶ recognize patterns (pattern recognition)
- ▶ understand application (functional understanding)
- ▶ audit all code (completeness)

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## Types of Programs

- ▶ <http://www.ouah.org/mixtercguide.html>
- ▶ setuid/setgid programs
- ▶ daemons and servers
- ▶ frequently run system programs
- ▶ system libraries (libc)
- ▶ widespread protocol libraries (kerberos, ssl)
- ▶ administrative tools
- ▶ CGI scripts, server plugins

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## Classes of Bugs to Audit

- ▶ API-based bugs
- ▶ external resource interactions
- ▶ programming construct errors
- ▶ state mechanics

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## API-based Bugs

- ▶ misuse of OS, library or framework APIs
- ▶ dangerous string or formatting functions: e.g., `sprintf()`, `strcpy()`, `strcat()`, `printf()`, `syslog()` ...
- ▶ dangerous implicit behavior: e.g., allocators that round
- ▶ cumbersome/complicated API reference contents: e.g., threading, IPC

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## External Resource Interactions

- ▶ privilege escalation through IPCs
- ▶ `system()`, `execve()`, `CreateProcess()`
- ▶ file interaction

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## Programming Construct Errors

- ▶ CWE: Common Weakness Enumeration  
<https://cwe.mitre.org/data/index.html>
- ▶ integer signedness
- ▶ integer boundaries
- ▶ checks that are logically wrong or susceptible to integer problems
- ▶ loops that have bad boundaries
- ▶ unchecked variables

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## State Mechanics

- ▶ programs left in an inconsistent state
- ▶ thread safety issues
- ▶ async-safety issues
- ▶ global variables left in an undesired state

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## Methodology

- ▶ target components, meta targeting
- ▶ grep targeting – won't provide understanding
- ▶ read code quickly – ignore what is not important
  - ▶ copy and move data
  - ▶ input/output

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## List of Issues

- ▶ implementation bugs (miscalculation, check result, not validate input)
- ▶ data types
- ▶ memory corruption

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## Defensive Programming

- ▶ sh\*t happens
- ▶ assume the worst, program accordingly
- ▶ secure programming / secure coding
- ▶ offensive programming
- ▶ formal verification
- ▶ rewrite vs reuse

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## Secure Coding

- ▶ <https://wiki.sei.cmu.edu/confluence/display/c/SEI+CERT+C+Coding+Standard>
- ▶ techniques for building secure programs
- ▶ handling input
- ▶ working with memory and buffers
- ▶ handle error/exceptions
- ▶ handling data types

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## Input Validation

- ▶ anything can be malicious
- ▶ look for injections
- ▶ take into account encoding
- ▶ only allow required format

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## Buffer Management

- ▶ start address and length
- ▶ boundary checking
- ▶ indexes

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## String Management

- ▶ length management
- ▶ NUL-byte termination
- ▶ string truncation
- ▶ printable characters

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## Integer Management

- ▶ conversions (size)
- ▶ overflows
- ▶ signedness

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## Keywords

- ▶ secure by design / implementation
- ▶ program analysis
- ▶ static analysis
- ▶ dynamic analysis
- ▶ source code analysis
- ▶ binary analysis
- ▶ code auditing
- ▶ bugs
- ▶ vulnerabilities
- ▶ programming errors
- ▶ CWE (*Common Weakness Enumeration*)
- ▶ defensive programming
- ▶ secure coding

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## Resources

- ▶ <https://www.amazon.com/Building-Secure-Software-Addison-wesley-Professional/dp/0321774957>
- ▶ <https://www.amazon.com/Secure-Coding-2nd-Software-Engineering/dp/0321822137>
- ▶ <https://wiki.sei.cmu.edu/confluence/display/c/SEI+CERT+C+Coding+Standard>
- ▶ [https://www.owasp.org/index.php/OWASP\\_Secure\\_Coding\\_Practices\\_-\\_Quick\\_Reference\\_Guide](https://www.owasp.org/index.php/OWASP_Secure_Coding_Practices_-_Quick_Reference_Guide)
- ▶ David Binkley: Source Code Analysis: A Road Map
- ▶ <https://cwe.mitre.org/data/index.html>
- ▶ <https://samate.nist.gov/SRD/testsuite.php>

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## References

- ▶ <http://pentest.cryptocity.net/code-audits/>
- ▶ <http://software.intel.com/en-us/articles/collection-of-examples-of-64-bit-errors-in-real-programs/>
- ▶ <http://www.ouah.org/mixtercguide.html>
- ▶ <http://www.vanheusden.com/linux/audit.html>
- ▶ <http://spinroot.com/static/>
- ▶ <http://spinroot.com/p10/>
- ▶ The Science of Code Auditing, BlackHat EU 2006
- ▶ <https://www.grammatech.com/products/binary-analysis>
- ▶ <http://bitblaze.cs.berkeley.edu/>
- ▶ <https://www.veracode.com/>

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