Software Fault Injection for Survivability

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Goals of Software Testing

- Correctness
- Reliability
- Usability
- Robustness
- Performance

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- Correctness
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- Robustness → Survivability
- Performance

Outline

- Basic definitions and Testing Technique Overview
- Algorithm for Fault Injection Analysis
- Fault Injection Security Tool (FIST)
- Interface Propagation Analysis (IPA)
- Conclusions

Some Basic Definitions

Information Survivability: “The ability of a system to continue to operate in the presence of faults, anomalous system behaviour, or malicious attack.”

Fault Injection: “The process of perturbing program behaviour by corrupting a program state during program execution.”

Three Primary Threats to Survivability:

- Software Flaws
- Malicious Attacks
- Anomalous Behaviour of Third Party Software

Three Primary Threats to Survivability:

- Software Flaws
  - We don’t know where the actual errors are
  - Simulate random flaws
- Malicious Attacks
  - Subject software to well-known attacks
- Anomalous Behaviour of Third Party Software
  - Libraries and COTS components may be flawed
  - Simulate component failure

Algorithm

P = Program under analysis

S = State of the system

x = Input value

l = Location in *P*

PRED = Security violation predicate (assertion) for *P* and *S*

Algorithm

1 – Execute *P* on selected input *x*

2 – Instrument code to determine each *l* in *P* that is exercised by *x.*

3 – Determine the outcome of an unperturbed run of *P*

4 – Alter some variable at location *l* (inject a fault)

5 – If security predicate (assertion) was violated, record location *l*

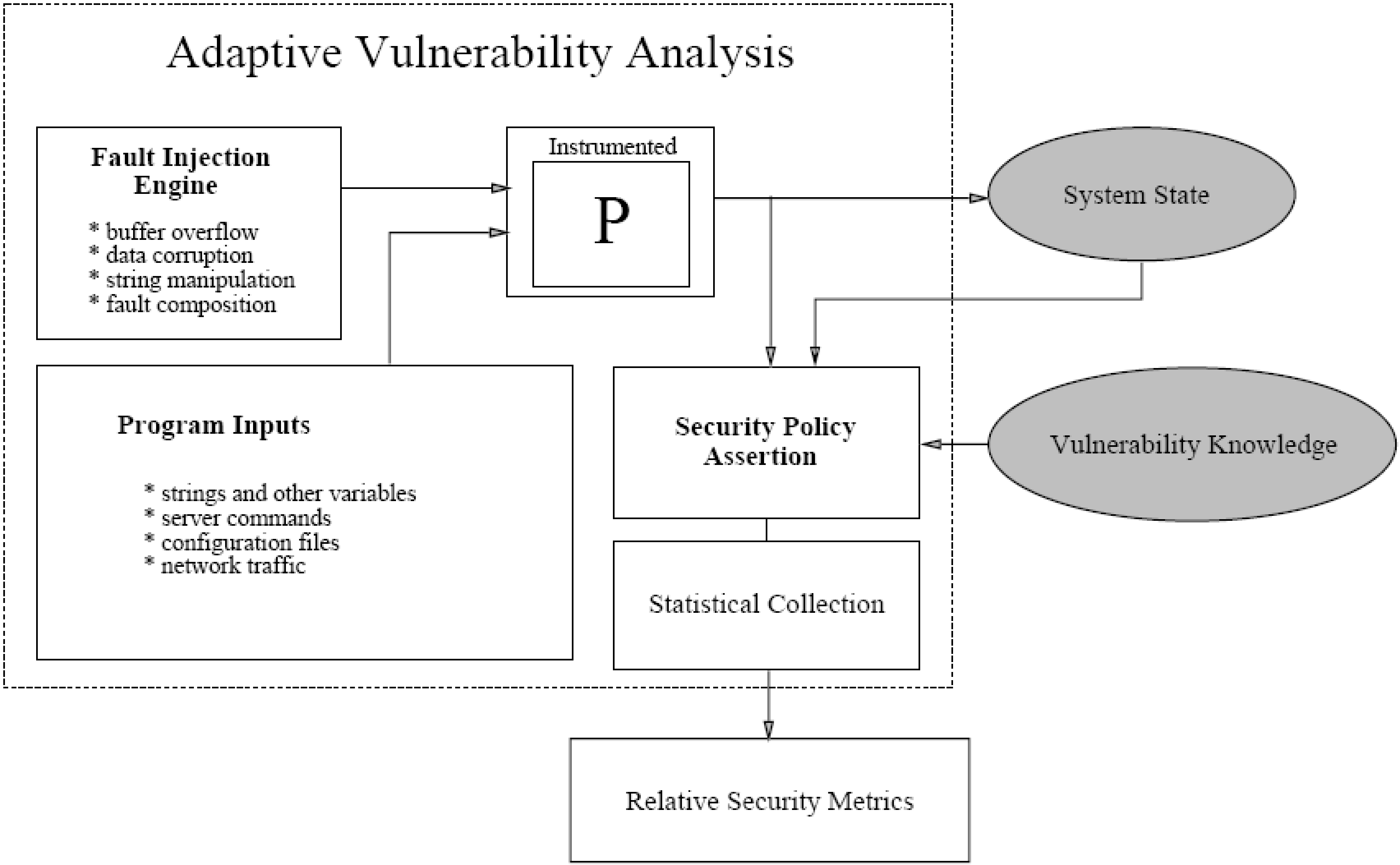
6 – Repeat steps 1-5 until coverage goals met

7 – Use recorded locations in code as basis of further analysis (code inspection, verification, etc)

FIST (Fault Injection Security Tool)

- Implementation of fault injection analysis algorithm
- C/C++
- Allows developer to:
  - Randomly perturb program states
  - Append or truncate strings
  - Attempt Buffer Overflows
  - Perform other fault injection functions

FIST


Adaptive Vulnerability Analysis
Fault Injection Engine
* buffer overflow
* data corruption
* string manipulation
* fault composition
Instrumented
P
System State
Program Inputs
* strings and other variables
* server commands
* configuration files
* network traffic
Security Policy Assertion
Vulnerability Knowledge
Statistical Collection
Relative Security Metrics

FIST

- Miscellaneous Reasons FIST is effective:
  - Always attempts to overflow buffers
    - Most tools only target specific, vulnerable functions
    - StackGuard, Fuzz
  - Allows users to specify “security violations” for individual applications under analysis
    - Choose from predefined assertions
    - Create your own assertions based on any C expression
  - Capable of external assertion monitoring

FIST

- FIST Analysis was performed over a variety of network service daemons
- Several potentially exploitable locations were identified
- Security violation identified in WU-FTPD was later independently discovered and reported by CERT-CC

IPA (Interface Propagation Analysis)

- Simulates component/subsystem failures
- Start from worst case assumptions, observe system-wide effects
- Unit performance is unimportant unless it affects the integrity of the entire system

IPA

IPA uses two fault injection algorithms:

- Propagation From

- Propagation Across

IPA

Propagation From

- Corrupts data exiting a component to observe the types of system failures that ensue.
- Provides information regarding semantic interactions between components as a measure of tolerance

IPA

Propagation Across

- Corrupts data entering a component
- Simulates input failure to gauge component’s robustness
- Mimic human operator errors, hardware failures, or failures from other subsystems

Conclusions

- Fault Injection Analysis can be used in an unconventional way to test survivability in several different scenarios:
  - Software flaws in program source code
  - Malicious attacks
  - Anomalous behaviour from third party software
- By identifying problem components and functions automatically, drastically reduce areas that require manual analysis

Questions?