System Testing & Performance

- System Testing
  - system testing vs. unit testing
  - planning for system testing
- Bug Finding
  - bug detection rates
  - release phases & ship criteria
- Performance Management
  - basic principles
  - performance design and repair
  - basic tools and practices

Unit vs. System Testing

- Goals
  - is this component ready to integrate?
  - is this system ready to ship?
- Context
  - testing components in relative isolation
  - testing the entire assemblage
- Focus
  - component functionality and specifications
  - system functionality and specifications
  - "whole system" behavior

Testing Responsibilities

- There are multiple players
  - developers
  - testers working with the developers
  - independent Test Group
- There are many types of testing
  - component functional validation
  - system functional validation
  - usability, security, performance, robustness
- Many theories about who should do which
  - organizational, philosophical, process, moral

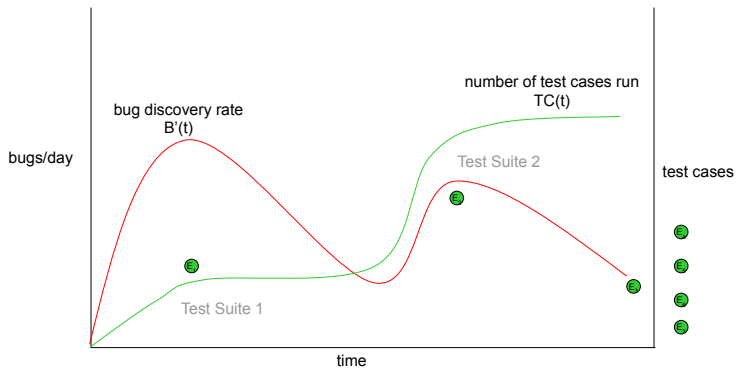
Typical System Test Activities

- System functionality and error handling
  - does the system do the things it is supposed to do
  - including the correct handling of all specified error conditions
- Installation (and upgrade) testing
  - do all of the parts install and configure correctly on all platforms
  - do upgrades properly preserve all persistent state
- Usability testing
  - can ordinary people figure out how to use it
- Security testing
  - authentication, authorization, privacy, attacks
- Interoperability testing
  - platforms, devices, different clients & servers
- Performance testing
  - capacity, throughput, response time
- Stress testing
  - overload, resource exhaustion, error recovery

Planning System Testing

- Some system testing is fairly obvious
  - does the whole system meet specified requirements
    - derive test cases from the requirements
  - fully exercise independent component interactions
    - derive test cases from architecture and specifications
- But what other tests do we need to include?
  - standard types of testing:
    - installation, usability, security, interoperability, performance
  - other types of product or domain specific testing?
- System Testing is about <u>confidence</u>
  - what will the product be expected to do?
  - what are we already confident that it can do?
  - what are we still not yet sure of?

Testing and Bug Discovery



Basic Principles of Performance

- The Pareto Principle
  - 80% of cycles are spent in 20% of the code
  - (my experience it is more like 90% and 2%)
- Performance requires real measurement
  - our intuition usually turns out to be wrong
- Performance demands eternal vigilance
  - if we aren't getting faster, we're getting slower
- Performance is mostly about design
  - code optimization is only occasionally useful

Design for Performance

- Establish performance requirements
- Anticipate bottlenecks
  - frequent operations (interrupts, copies, updates)
  - limiting resources (network/disk bandwidth)
  - traffic concentration points (resource locks)
- Design to minimize problems
  - eliminate, reduce use, add resources
  - and, sometimes, optimize implementation
- Include performance in design reviews

Fixing Performance Problems

- is a lot like finding and fixing a bug
  - formulate a hypothesis
  - gather data to verify your hypothesis
  - be sure you understand underlying problem
  - review proposed solutions
    - for effectiveness
    - for potential side effects
  - make simple changes, one at a time
  - re-measure to confirm effectiveness of each
- only harder

For Next Lecture

- McConnell 30.2, source-code tools)
- McConnell 31, layout and style
- McConnell 32.1-4, commenting
- McConnell 34.3, understandability
- McConnell 34.5, conventions
- Wikipedia: Doxygen
  - documentation generation

Supplementary Slides

Pre-FCS Exposure

- give key customers an early sniff
  - so they can better prepare for new release
  - so they can start work on related products
- get additional feedback prior to FCS
  - real customers will use it in different ways
    - they will find different bugs
    - they will find usability issues
    - they will find compatibility issues
- obscure the fact we are behind schedule
  - we shipped something!

Alpha Testing

- alpha products are usually incomplete
  - missing functionality and documentation
  - very buggy
  - non-standard installation and management
- alpha sites are carefully selected
  - they are prepared to deal with problems
  - they can be trusted to exercise the product
- goals of alpha testing
  - gather feedback on key features and content
  - early access for partners, key customers

Beta Testing

- a beta product is very near final form
  - all functionality and documentation complete
  - few significant known problems
- beta sites are real customers
  - they will put the product to real use
  - they have agreed to give us feedback
- goals of beta testing
  - confirm the product is ready to ship
  - gather last-minute feedback
  - early access for key customers

determining ship-ability

- many types of metrics are commonly used
  - list of tests that must be passed
  - hours of load/stress tests passed
  - performance criteria
  - beta report results
  - open bug counts
  - new bug arrival rates
- concurrence (engineering, Q/A, support)
- fiat (product executive says “ship it”)
- criteria must be set at start of project

In-System Unit Testing

- test new component in a whole system
  - other components with which to interact
  - we are able to exercise more functionality
  - we can identify component interface issues
- add new component to existing system
  - where other components are known good
- test builds of experimental components
  - tracking down problems can be difficult
- this is still unit, and not system testing

Functionality Testing

- does system function as specified?
  - test all specified functional requirements
  - these are part of the acceptance criteria
- may involve a large number of test cases
  - many may be existing unit test cases
  - may include standards conformance suites
  - may include whole-system exercises
  - may include sample scenarios
- this testing should be automated

Robustness Testing

- introduce each specified error
  - invalid options, requests, and data
  - communications errors, resource failures, ...
- verify correct system response
  - check that system properly detects it
  - check that system properly reports it
  - check that system properly responds to it
  - check that system continues working
- this testing should be automated

Installation Testing

- installation is functionality too
  - component install may be checked w/unit test
- whole system install also needs testing
  - follow directions and use the defaults
  - try all of the options and combinations
  - is feedback correct
  - is correct software installed correctly
  - does upgrade work (preserving old data)
- some automated testing, some manual

Usability Testing

- most testing should be automated
  - so that it can be run frequently
  - so that it is run consistently
- this should be complemented with usage
  - users sit down and try to use the software
  - they try do do normal things
  - they try to make obvious mistakes
  - such testing turns up many problems
  - but at some point, the pay-off falls off

Security Testing

- much of this is specified functionality
  - authentication/authorization mechanisms
  - data protection mechanisms
  - response to unauthorized requests
  - covered by automated functionality test cases
- it is also necessary to look for holes
  - design review by domain security experts
  - penetration tests by experienced hackers

InteroperabilityTesting

- consider everything system depends on
  - hardware, operating system, other services
  - there are probably multiple versions of each
- consider everything system talks to
  - browsers, servers, routers, etc.
  - there are probably multiple versions of each
- we should test on all combinations
  - or one from each equivalence partition
  - defining these requires insight an experience

Stress Testing

- bugs are often found in special cases
  - resource exhaustion, error handling
  - unlikely combinations of events
- stress tests create these continuously
  - traffic generators running at full capacity
    - with changing random mixes of requests
  - continuous error generation
    - with random error selection
- stress tests can run for days or longer
  - they shake out many hard-to-cause problems

Load Generation

- system specifications include capacity
  - support up to 3000 transactions/second
- performance should be measured <u>at load</u>
  - response time a 1500 transactions/second
- many bugs involve concurrent operations
  - locking, allocate/free, protection, etc.
- these require automatic load generation
  - generate traffic of specified types
  - generate traffic at calibrated rates

Performance Testing

- identify key performance metrics
  - throughputs, response times, capacities
  - some may be external competitive numbers
  - some may be internal assessment numbers
- define ways to measure each
  - test transactions and measurement points
- write suites to exercise and measure
  - there are often performance benchmarks
- this testing should be automated

Performance: what to measure

- competitive performance metrics
  - used to compare competing products
    - nominal response time for simple query
    - standard transactions per second
- engineering performance metrics
  - used to spec components
  - used to analyze performance problems
    - time to perform a particular sub-operation
    - channel utilization, idle time, cycles per operation
- must be meaningful and well defined

Perf: meaningful measurements

- measure under controlled conditions
  - on a specified platform
  - under a controlled and calibrated load
  - without other conflicting activities
- ensure validity of results
  - measuring very brief operations
    - ultra-high resolution timers
    - perform a large number of operations
  - repeatability of results
    - collect many samples, explain variations

Execution Profiling

- automated measurement tools
  - compiler options for routine call counting
    - one counter per routine, incremented on entry
  - statistical execution sampling
    - timer interrupts execution at regular intervals
    - increment a counter in table based on PC value
    - may have configurable time/space granularity
  - tools to extract data and prepare reports
    - number of calls, time per call, percentage of time
- very useful in identifying the bottlenecks

Execution Profiling

Simple execution profiling

%time	seconds	cum %	cum sec	procedure (file)
42.9	0.0029	42.9	0.00	printit (profsample.c)
42.9	0.0029	85.7	0.01	add_vector (profsample.c)
14.3	0.0010	100.0	0.01	mult_by_scalar (profsample.c)

Profiling with call counting

% time	cumulative seconds	self seconds	calls	self ms/call	total ms/call	name
42.9	0.0029	0.0029	2200	0.0013	0.0013	printit
42.9	0.0058	0.0029	20	0.1450	0.1450	add_vecto
14.3	0.0068	0.0010	2	0.5000	1.2225	mult_by_scalar
0	0.0058	0.0000	1			main

Time Stamping

- application instrumentation technique
- create a log buffer and routine
  - call log routine for all interesting events
  - routine stores time and event in a buffer
    - requires a cheap, very high resolution timer
- extract buffer, archive, mine the data
  - time required for particular operations
  - frequency of operations
  - combinations of operations
  - also useful for post-mortem analysis

Time Stamping

Dump of simple trace log

date	time	event	sub-type
05/11/06	09:02:31.207408	packet_rcv	0x20749329
05/11/06	09:02:31.209301	packet_route	0x20749329
05/11/06	09:02:31.305208	wakeup	0x4D8C2042
05/11/06	09:02:31.401106	read_packet	0x033C2DA0
05/11/06	09:02:31.401223	read_packet	0x033C2DA0
05/11/06	09:02:31.402110	sleep	0x4D8C2042
05/11/06	09:02:31.614209	interrupt	0x00000003
05/11/06	09:02:31.614209	dispatch	0x1B0324C0
05/11/06	09:02:31.614210	intr_return	0x00000003
05/11/06	09:02:31.652303	check_queue	0x2D3F2040
05/11/06	09:02:31.652306	packet_rcv	0x20749329