Quality Attribute Scenarios and Architectural Tactics

15-313:
Foundations of Software Engineering

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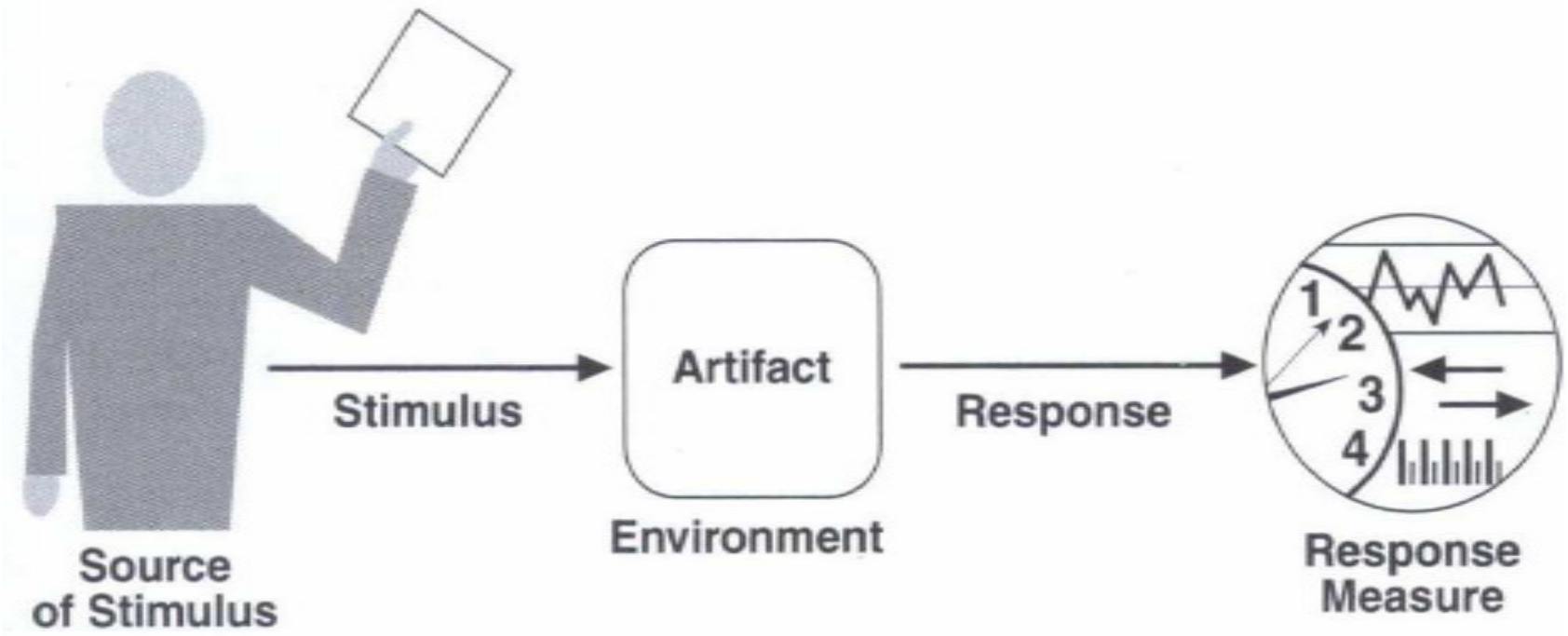
Source

[BCK03] Bass, Clements, and Kazman. *Software Architecture in Practice.* Addison-Wesley, 2003.

Quality Attribute Scenarios [BCK03]



- Stimulus
  - A condition that affects a system
- Source of stimulus
  - The entity that generates the stimulus
- Environment
  - The condition under which the stimulus occurred
- Artifact
  - The artifact that was stimulated
- Response
  - The activity that must result from the stimulus
- Response measure
  - The measure by which the response is evaluated

Availability

- Is the system able to provide services to users?
  - Often measured as a probability

- Issues
  - faults → failures
    - can intervene to avoid this
  - fault/failure detection
  - failure notification
  - failure recovery
    - how long to repair?

Availability Scenarios

Scenario Portion	Possible Values
Source	Internal vs. external to system
Stimulus	Crash, omission, timing, incorrect response
Artifact	System's processors, communication channels, persistent storage, processes
Environment	Normal operation; degraded mode
Response	Log the failure, notify users/operators, disable source of failure, be unavailable, continue (normal or degraded mode)
Measure	Time interval available, availability %, repair time, unavailability time interval

How to Increase Availability?

- Architectural Tactic
  - strategy for promoting quality attribute
  - independent of implementation technology
  - independent of exact architectural structure

- Three kinds of Availability Tactic
  - Fault detection
  - Fault recovery
  - Fault prevention

Availability Tactics: Fault Detection

- ping/echo
  - ping another component
  - expect an echo before a timeout
- heartbeat
  - expect periodic message
- exceptions
  - detect generated exception

Availability Tactics: Fault Recovery

- voting
  - multiple components produce answer
  - give client the answer with the most votes
  - most useful for hardware failures
    - buggy software will fail in the same way
      - occurs even if built by different teams!
- active replicas
  - all replicas respond to all messages
- passive replicas
  - passive replicas periodically updated with current state
  - requires limited replay
- spare
  - must boot, load checkpoint, and replay recent messages
- checkpoint/rollback
  - allows undoing operations after a failure

Availability Tactics: Fault Prevention

- remove from service
  - e.g. reboot a component that's getting low on memory
    - surprisingly effective for OS drivers
- transactions
  - avoids failures/inconsistencies when part of an operation fails
- process monitor
  - detect fault in running process, then restart and reinitialize before errors propagate

What is the cost of these tactics?

Modifiability

- What is the cost of change?

- Issues
  - What is changing?
    - functions, platforms, hardware, protocols…
    - quality attributes
  - Who changes it?
  - When is it changing?

Modifiability Scenarios

Scenario Portion	Possible Values
Source	End-user, developer, system-administrator
Stimulus	Add/delete/modify functionality or quality attributes
Artifact	System user interface, platform, environment
Environment	At runtime, compile time, build time, design-time
Response	Locate places in architecture for modifying, modify, test modification, deploys modification
Measure	Cost in effort, money, time, extent affects other system functions or qualities

Modifiability Tactics

- Localize modifications
  - Modifications affect the requirements of as few modules as possible
- Prevent ripple effects
  - Limit effect of changing one module on other modules
- Defer binding time
  - Allow modifications late in process at low cost

Modifiability Tactics: Localization

- Maintain semantic coherence
  - group responsibilities that are likely to change together in the same module
- Hide information based on anticipated changes
  - organize architecture to minimize number of modules affected by *specific* changes
- Generalize the modules
  - the more general the module's interface, the more likely changes in requirements won't require changing the interface or the implementation
    - BUT – generality creates complexity and cost, so only use it if you need it
- Limit possible options
  - Restrict the set of possible changes so that you can plan better for the supported changes

Modifiability Tactics: Prevent Ripples

- Key issue: Notion of interfaces
  - types and signatures, semantics, sequences
  - identity, location, existence
  - quality of service, resource use
- Tactics
  - Hide information (like the above) within a module
  - Maintain interfaces
    - Extend in backwards compatible way, add an adapter
  - Restrict communication paths
    - Fewer connections along which ripples can propagate
  - Add an intermediary
    - Convert data types, replace interfaces with a proxy
    - Hide identity using broker, location using name server
    - Resource manager hides resource behavior

Modifiability Tactics: Deferring Binding

- Event registration
  - Plug-and-play connection between components
  - Cost in understandability
- Polymorphism
  - Late binding of method calls
  - Cost in performance
- Configuration files
  - Bind at deployment
  - Cost in complexity

Performance

- How long does it take the system to respond to an event?
  - Generalizes to throughput, etc.

- Issues
  - Sources of events
    - end users, interrupts, timers, messages
  - Arrival patterns
    - periodic, sporadic, stochastic
  - Response criteria

Performance Scenarios

Scenario Portion	Possible Values
Source	A number of sources both external and internal
Stimulus	Periodic events, sporadic events, stochastic events
Artifact	System or component
Environment	Normal mode; overload mode
Response	Process stimuli; change level of service
Measure	Latency, deadline, throughput, jitter, miss rate, data loss

Performance Tactics

- Fundamental issues
  - Resource use
    - computation, memory, bandwidth, system-specific resources
  - Blocking for resources
    - contention, availability, dependencies

- Strategies
  - Reduce resource demand
    - Increase efficiency, lower performance expectations
  - Increase resources
    - Throw money at the problem
  - Coordinate resources
    - Share more efficiently

Performance Tactics: Reduce Demand

- Increase efficiency
  - Better algorithms
  - Trade space for time
- Reduce overhead
  - Avoid costly operations, e.g. indirection
    - Typically conflicts with other quality attributes!
- Reduce event rate
  - Sample environmental data less frequently
    - May reduce precision
- Discard events
  - Sample from input stream
    - Cost: some requests are lost
- Bound execution time
  - e.g. number of iterations in problem
    - Cost: solution may be less precise

Performance Tactics: Increase Resources

- Introduce concurrency
  - Adds complexity, but gets things done faster if there is inherent parallelism
- Duplicate data or computation
  - Avoid contention for shared resources
  - Cache data from a remote server
- Buy more resources
  - Faster CPU, more CPUs, more memory, faster network
  - Only barrier is $$$
    - So, does the value of the additional performance exceed its cost?

Performance Tactics: Coordinate Resources

- Typically scheduling strategies
  - FIFO
    - fair when all requests are equivalent
  - fixed priorities
    - most important
    - shortest deadline
  - dynamic priorities
    - earliest deadline first
  - static scheduling
    - allocate everything up front
    - good for real-time / embedded systems

Security

- Ability to resist attack while remaining functional

- Issues
  - Confidentiality – can't see private data
  - Integrity – can't modify data without permission
  - Nonrepudiation – can't deny malicious action
  - Availability – no denial of service

Security Scenarios

Scenario Portion	Possible Values
Source	User/system that is identified correctly/incorrectly or unknown, who is internal/external and authorized or not, with full/limited access
Stimulus	Attempt to display/modify data; access services; reduce availability
Artifact	System services, data
Environment	Online/offline, connected/disconnected, firewalled/open
Response	Grant/block access; audit requests; encrypt data; detect attack; enter degraded mode
Measure	Cost/benefit of attack to attacker, cost of attack to defender and users; probability of identifying attacker; availability during DOS attack; …

Security Tactics: Resisting Attacks

- Authentication
  - User identification – often username/password
- Authorization
  - Which users can perform which operations?
- Encryption
  - Protect confidential data
- Checksums / signatures
  - Ensure integrity of data
- Principle of least privilege
  - Reduce damage attacker can do
- Limit access
  - Firewalls, etc.

Security Tactics: Detection/Recovery

- Intrusion detection systems
- Audit trails
- Availability tactics

More Quality Attributes

- Testability
- Usability
- Interoperability
- Scalability (Performance? Modifiability?)
- Portability (Modifiability)