Software Quality, Verification, and Validation

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Chapter no. 1

Software Quality, Verification, and Validation

1.1 Introduction

1.1.1 Problems in our society

Our society depends on software, cars, water, energy, computers, everything is controlled by software.
Flawed software will hurt profits, fixing a bug after release and delivery is much more expensive than fixing it before its release. Even if bugs aren't noticeable by the end users or the company hosting it, bugs can lead to security exploits, and later breaches.
Flawed software can even hurt users directly, e.g. pacemaker crashing or av making a wrong turn.

1.1.2 Why this course

- What is "good" software?

  we determine this through quality dependencies

- What is the key to good software?s

  Verification and Validation.

- Exploration of testing and analysis activities of the V and V process

1.2 When is software ready for release?

1.2.1 The short answers

- We can't find any bugs
- When we have finished testing
- When quality is high

1.2.2 The long answer

We all want high-quality software, but be don't all agree what that means.

- We can't find any bugs

  but we can't find all bugs.

- When we have finished testing

  but we can't test everything.

- When quality is high

  but we don't know what that means.

We need to define what we mean by quality, and how we can measure it.

Quality attributes

- Performance

  Ability to meet timing requirements
- Security

  Ability to protect information
- Scalability

  Ability to grow the system to process more concurrent requests
- Availability

  Ability to carry out the task whenever needed
- Modifiability

  Ability to enhance the software to meet new requirements or fix bugs
- Testability

  Ability to easily find faults in the software
- Interoperability

  Exchange information with other systems
- Usablility

  Ability to be used by the intended audience and perform required tasks

  How easy it is to learn to use the software

These can easily conflict with each other, its important to decide what to prioritize and set a threshold of what's good enough.

1.2.3 When is software ready for release?

It's ready for release when it's **dependable**. This means it needs to be correct, reliable.

1.3 Verification and Validation

1.3.1 Verification

The process of checking that a system meets its requirements.
Are we building the product right?
Verification is an experiment. We perform trials, evaluate the results, and gather information about what and why it happened.

Testing

An investigation into system quality, it's based on sequences of stimulations and observations. The software version of a lab rat we later dissect to analyze what failed.

1.3.2 Validation

The process of proving that it meets the specifications set by the customer.
Are we building the right product?
Does the product work in the real world? Even if the software does exactly what we set out to do, it might not be what the customer wants.

1.3.3 Conclusion

Verification checks if the software works as intended.
Validation checks that the software is useful. (This is much harder)

Both are important and complete each other. This class however, focuses largely on verification.

- Testing is the primary activity of verification.

1.4 Required level of V and V

Depends on:

- Software Purpose

  The more critical, the more important that it works

- User Expectations

  Some users are more forgiving than others

- Marketing environment

  With competing products in a market, it might be more important to release a product quickly than to make it perfect.

1.4.1 Basic questions

1. When do verification start and end?
   - It should start as soon as the project starts
     we need to know what we're building and how design/technical choices affect our product's quality
     A great starting point is static verification
   - It ends when the product is released
     A great way of verifying during the development process is through dynamic verification
2. How do we obtain an acceptable level of quality at an acceptable cost?
3. How do we decide when it's ready to release?
4. How can we control quality during the development process?

1.5 Trade offs

There's always a trade-off when designing software, "Better, faster, or cheaper - pick any two".

1.5.1 Verification Trade-offs

We are interested in proving that a program demonstrates property X

- Pessimism inaccuracy

  Not guaranteed to program even if X is true

- Optimism inaccuracy

  May be true, even if X is false

- Property Complexity

  if X is too difficult to check, substitute with simpler property Y

Finding all faults is nearly impossible, instead we need to decide ourselves when we are ready for release, how good is good enough?

We need to establish criteria for what is good enough, and what is not. One way of doing this is through **Alpha/Beta testing** where a small group of users gets the chance to use the product in a somewhat controlled environment and reports feedback and failures.

Chapter no. 2

Quality Attributes and Measurement

2.1 Quality Attributes

Developers prioritize attributes and design systems that meet their needs.

2.1.1 Availability

Ability to avoid completely or recover quickly from failures. Redundancy.

2.1.2 Performance

Ability to meet timing or throughput requirements. The system needs to be able to respond quickly to events.

2.1.3 Scalability

Ability to scale the system performance to meet increased load. The system needs to be able to handle more concurrent requests.

2.1.4 Security

Ability to protect information. The system needs to be able to protect information from unauthorized access while still allowing authorized access.

2.2 Scalability

2.2.1 When is software ready for release?

It's ready for release when it's **dependable**. This means it needs to be correct, reliable, safe, and robust.

Correctness

A program is correct if it is always consistent with its specification. This depends on quality and detail of requirements, it's really easy to build a correct program with a weak specification, but if it's too detailed it becomes impossible to prove your program is completely correct.

More often than not, correctness is something we aim for, not prove.

Reliability

A statistical approximation of correctness, the probability that the program will perform correctly during a given period of time under a given set of conditions. We test reliability by running the program as different types of user profiles, and mainly focuses on reliability for our target audience.

Dependence on specifications

Correctness and reliability are dependent on the quality and strength of the specification. The more detailed the specification, the more likely the program is to be correct and reliable in the real world.

Correctness and reliability doesn't consider the severity of different crashes and bugs, a program that crashes once a year is more reliable than one that crashes once a day while in the real world it might be better with a daily crash than leaking all personal data once a year.

Safety

Safety is the ability to avoid hazards. We specify a set of undesirable situations, hazards, and prove that our program avoids them.

Robustness

Software that is correct may fail when our design assumptions are violated; *how* it fails matters. Software that gracefully fails is robust, e.g. if we tries to save a program to a read-only disk, the program should tell us what wet wrong gracefully instead of crashing.

Robustness cannot be proven, but is rather a goal to aspire to.

2.2.2 Dependability

We could have software that is reliable, but not correct, or correct but not safe, or robust but not safe. We need to consider all of these attributes when we talk about dependability.

Measuring Dependability

We need to establish criteria for when our system is dependable enough for release.
Correctness is too hard to prove conclusively for most programs.
Robustness and safety is important, but doesn't prove that our program functions correctly.
Reliability is the basis for arguing dependability, we can measure it, and we can demonstrate it through testing.

2.3 Reliability

Reliability is the probability of failure-fre operation for a specified time in a specified environment for a given purpose. This depends heavily on the system and user type.

2.3.1 Improving reliability

Reliability is improved when faults in our most frequently used parts are removed, this means that a program is more or less reliable for different users.

2.3.2 Reliability is measurable

Reliability can be defined and measured. We can specify requirements (both functional and non-functional) and measure how well our program meets them.

2.3.3 How to measure reliability

Hardware metrics often aren't suitable for software, since in hardware it can only hard crash and we can assume that the design of the hardware is correct.

With software most of the failures are design failures, and when a system has failed the system is often still available.

Availability

Can the software carry out its given task when needed. Can the system avoid failures, and recover quickly from failures. Can the system beep working for other users when it has crashed for one?

Availability is only a measurement of whether the system is available, not whether it's correct or reliable meaning incorrect computations or security isn't considered.

Availability is also a standalone quality attribute. We can through design prevent, tolerate, remove, or forecast failures. We can keep our system partially available more easily than hardware.

Probability of Failure on Demand (POFOD)

Likelihood that a single request will result in failure. A POFOD of 0.001 means that there is a 0.1% chance that a single request will fail. This is used in situations where failure is unacceptable, e.g. a medical system.

Rate of Occurrence of Fault (ROCOF)

Frequency of occurence of unexpected behaviour. A ROCOF of 0.02 means that we have 2 failure per 100 time units. Is appropriate when requests are made regularly, like a web server.

Mean Time Between Failures (MTBF)

Average time between failures. If we have a system that is used for long sessions, especially where users might only save their data once every few hours or so, it might be important to prevent crashes happening too often.

2.3.4 Reliability Metrics

- Availability: $\frac{\text{Uptime}}{\text{Total time observed}}$
- POFOD: $\frac{\text{Failures}}{\text{Requests over period}}$
- ROCOF: $\frac{\text{Failures}}{\text{Time elapsed in target unit}}$
- MTBF: Average time between observed failures.
- MTTR: Average time to recover from failures.

It may be cheaper to accept some unreliability and pay for failure cost instead of trying to make the system more reliable. This depends on social/political factors.

2.4 Performance

The ability to meet timing or throughput requirements. This is the driving factor in software design, even though it is often at expense of other quality attributes. All systems have performance requirements, but they are often not specified. Bad performance leads to a decrease in users.

2.4.1 Performance Measurements

- Latency

  The time between arrival of stimulus and the systems response to it.
- Response Jitter

  The allowable variation in latency.
- Throughput

  Usually number of transactions per unit time.
- Deadlines in processing
- Number of events not processed

Latency

Time it takes to complete an interaction, how quickly the system responds to a user. We measure latency probabilistically, e.g. 95% of requests are completed within 100ms.

Another type of latency is the turnaround time, the time it takes to complete a larger task, e.g. With daily throughput of 850,000 requests, process should take ¡ 4 hours, including writing to a database.

Response Jitter

Response time is non-deterministic, if we have an average latency of 5 seconds, we might have a latency of 2 minutes at a specific time, response jitter defines how large the maximum latency can be.

Throughput

The workload a given system can handle, usually measured in transactions per unit time. Since a larger throughput can lead to a longer service time, this can conflict with latency requirements.

Deadlines

Some special tasks must take place at a specific time.

Missed events

If our system is busy, we might need to ignore some events. This is usually a problem for real-time systems.

2.5 Scalability

The ability to process an increasing number of requests. There are two types of scalability:

- Horizontal scalability

  Adding more resources to the system, e.g. adding more servers to a web server farm.
- Vertical scalability

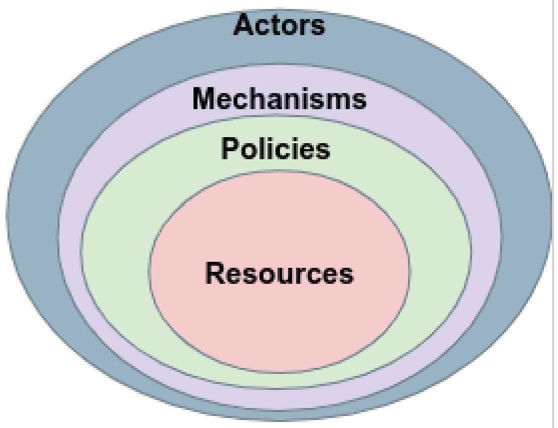
  Adding more power to a single resource, e.g. adding more RAM to a single server.

How can we effectively utilize additional resources? This requires that additional resources:

- Result in performance improvement
- Didn't require undue effort to add
- Did not disrupt operations
- **Must be designed to scale**

2.6 Security

Ability to protect data and information from unauthorized access while still providing access to authorized people and systems.



Processes allow owners of resources to control access. Actors are systems or users. Resources are sensitive elements, operations, and data of the system. Policies define legitimate access to resources.

2.6.1 Security Characterization (CIA)

Confidentiality, Integrity, and Availability.
Authentication, Nonrepudiation and Authorization are also important.

2.6.2 Security Approaches

We achieve security by detecting, resisting, reacting, and recovering from attacks. Data needs to be protected, both when in transit or when at rest.

Security is a process, not a product. Nothing is completely secure or unsecure, and all systems will be compromised. We need to be able to detect and recover from attacks as well as figure out who attacked.

2.6.3 Assessing Security

Measure of system's ability to protect data from unauthorized access while still providing service to authorized users. we need to assess how well system responds to attack. We can respond by e.g. logging, blocking, or shutting down the system.

There isn't one single metric for measuring security, in some cases what data is more important, in some cases how much data was lost.

2.7 Key points

Dependability is one of the most improtant software characteristicts. Reliability depends on the pattern of usage of the software, different users will interact differently.
Reliability measured using ROCOF, POFOD, AVAILABILITY, MTBF, MTTR.
AVAIlability is the ability of the system to be available for use. Performance is about management of resources in the face of demand to achieve acceptable timing Scalability is the ability to "grow" the system to process an increasing number of requests Security is the ability to protect data and information from unauthorized access Security is not "measured", but requires defining attacks and actions to prevent or reduce impact of risk, then assessing those actions

Chapter no. 3

Quality Scenarios

3.1 Scenarios

A scenario is a description of an interaction between external stuff and the system. It defines:

- An event that triggers the scenario.
- An interaction initiated by the external stuff.
- What response is required.

This is similar to use cases or user stories, but examines **both** quality and functionality.

We use scenarios to capture a wide range of requirements:

- A set of interactions with users to which a system must respond
- Processing in response to timed events
- Peak load situations
- Regulator demands
- Failure response
- Maintainer changes stuff
- Whatever the design is required to handle

3.1.1 Scenario usages

Scenarios are used to; provide input to architecture definitions, by helping fleshing out your requirements and finding new ones; Evaluate system architecture, by finding missing or incompatible interfaces; communicating with stakeholders, gives easy to understand examples of what the system can do; driving the testing process by helping prioritizing your testing.

3.1.2 Scenario format

Overview

A brief description of what the scenario is.

External stimulus

What initiated the scenario? A user request, a timer, a failure, a maintainer, etc.

System state

Aspects of the system's internal state that might affect quality, such as does data exist already? is the system under high or low load, and so on.

System environment

How does the environment around the system look? How does our infrastructure look? Does the system have gigabit ethernet? is the system air gapped?

System response

How does the system respond to our stimuli? How should the system respond to meet our quality requirements?

Response measure

How does we judge the quality of the response?

3.1.3 Response measure

Most quality measurements are non-deterministic. All time-based measures should be probabilistic (95% of the time the response should be N, 99% of the time it's M).

For real-time systems all time measurements should give a worst-case response time. Otherwise you can give an absolute threshold.

3.1.4 What do we do with scenarios?

We use them primarily to test and improve our design. It's also a great way of showing to stakeholders what the system can do and how it can be used.

We also use scenarios for exploratory testing, where humans are used to test the system. We also use them for formal test cases.

3.1.5 What is a good scenario?

credible, valuable, specific, precise, comprehensive

- credible

  it should be a realistic scenario
- valuable
- precise
- specific
- comprehensive

3.1.6 Effective scenario use

Identify a focused set of scenarios that are representative of the system's behavior. Too many scenarios can be a hindrance, no more than 20 scenarios.

Use distinct scenarios, it's much better to have wildly different scenarios than to have a few scenarios that are very similar.

Use scenarios early, they are most important in the early phase, later on it can be hard to change the system behaviour after a new set of scenarios.

3.1.7 Reliability scenarios

The ability to minimize the number of observed failures. These resolve around one function accessed through an interface.

Reliability scenario format

- Overview

  Highlight the function(s) being used and which context they are used in
- System state

  Data stored or past events may impact our reliability
- Environment state

  Our available resources can change how reliable our system is, an underpowered processor may cause a system to fail.
- External stimulus

  A user or external system performs one or more input actions

  State specific interactions performed

  If relevant, the type of user and how they perceive reliability
- Required response

  The functional response of the system
- Reliability measure

  how should we measure the reliability of the system and how reliable should it be?

3.1.8 Availability scenarios

Ability of the system to mask or repair failures such that the outage period does not exceed a required value over a time period. In other words, we look at how the system responds to a failure, how long it takes, and what it does to return to normal operation.

We need to distinguish between failures and the software's perception of failure, e.g. when the network goes down, the system doesn't count that as a failure until it needs to access the network, meaning we have time to recover.

Scenarios tends to deal with; failure of internal components or external systems, reconfigure of the physical system, or maintenance/reconfigure of the software.

Availability scenario format

- Overview

  Highlight the function(s) being used and which context they are used in.

- System/environment state
- External stimuli

  stimuli is omissions, crashes, wrongful timings, incorrect responses and so on.

- Required response

  Failure needs to be detected and isolated before we can recover.

- Response measure

  Can specify an availability percentage

  Can specify a time to detect/repair or when it needs to be available and for how long

3.1.9 Availability vs Reliability

Reliability is about how it operates normally and how often it fails. Availability is about how it operates when it fails and how we avoid hard crashes and downtime.