



Chapter 7: Software Construction for Robustness

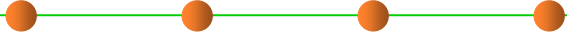
7.1 Robustness & Correctness

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Robustness & Correctness

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- **What are Robustness and Correctness?**
 - **How to measure Robustness and Correctness?**
 - **Objectives of this chapter**



1 What are Robustness & Correctness?



Robustness

- **Robustness(鲁棒性/健壮性):** “the degree to which a system or component can function correctly in the presence of invalid inputs or stressful environmental conditions” (IEEE Std 610.12-1990) 系统或组件在存在无效输入或压力环境条件时可以正确运行的程度
- **Robust programming**
 - A style of programming that focuses on **handling unexpected termination and unexpected actions**. 鲁棒性编程关注异常终止和异常活动的处理
 - It requires code to handle these terminations and actions **gracefully** by displaying accurate and unambiguous error messages. These error messages allow the user to more **easily debug** the program.

Robustness principle (Postel's Law)

■ Robustness principle (Postel's Law):

- Be conservative in what you do; be liberal in what you accept from others.
- “**Be conservative in what you send, be liberal in what you accept**”
- In other words, programs that send messages to other machines (or to other programs on the same machine) should conform completely to the specifications, but programs that receive messages should accept non-conformant input as long as the meaning is clear.
- 对自己做的事情保守（满足specification），对接收的信息自由（能够处理各类情况）。严于律己，宽于待人！

Principles of robust programming

- **Paranoia(偏执狂) - Don't trust anything you don't generate!** When building software, the programmer assumes users are out to break their code. The programmer also assumes that his or her own written code may fail or work incorrectly. 程序员认为使用者会破坏代码，代码也会运行失败和工作不正确。
- **Stupidity - Assume that the caller or user is an idiot, and cannot read any manual pages or documentation.** The programmer assumes users will try incorrect, bogus and malformed inputs. 程序员认为用户不会阅读specification(不遵守约定)
 - As a consequence, the programmer returns to the user an unambiguous, intuitive error message that does not require looking up error codes.
 - The error message should try to be as accurate as possible without being misleading to the user, so that the problem can be fixed with ease. 返回明确的错误信息，有助于问题更容易的被修复

Principles of robust programming

- **Dangerous implements** - Users should not gain access to libraries, data structures, or pointers to data structures.
 - **This information should be hidden from the user** so that the user doesn't accidentally modify them and introduce a bug in the code.
 - When such interfaces are correctly built, users use them without finding loopholes to modify the interface.
 - The interface should already be correctly implemented, so the user does not need to make modifications. **The user therefore focuses solely on his or her own code.**
- **Can't happen** - Very often, code is modified and may introduce a possibility that an “impossible” case occurs. **避免发生小概率事件**
 - Impossible cases are therefore assumed to be highly unlikely instead.
 - **The developer thinks about how to handle the case that is highly unlikely**, and implements the handling accordingly.

Correctness

- **Correctness** is defined as the software's ability to perform according to its specification. 正确实现规格说明的能力
- **Robustness vs. correctness:** at opposite ends of the scale.
 - **Correctness** means never returning an inaccurate result; no result is better than an inaccurate result. 永远不要返回不准确的结果，无结果优于不准确的结果
 - **Robustness** means always trying to do something that will allow the software to keep operating, even if that leads to results that are inaccurate sometimes. 总是尝试做些事情，确保软件运行，及时有时会产生一些不准确的结果
- Robustness adds built-in tolerance for common and non-critical mistakes, while correctness throws an error when it encounters anything less than perfect input. 健壮性增加了对常见错误和非严重错误的容错，而正确性在遇到任何不完美的输入时会引发错误。

Comparison of Robustness and Correctness

Problem	Robust approach	Correct approach
A rogue web browser that adds trailing whitespace to HTTP headers. 增加错误的空格	Strip whitespace, process request as normal.	Return HTTP 400 Bad Request error status to client.
A video file with corrupt frames. 错误的帧	Skip over corrupt area to next playable section.	Stop playback, raise "Corrupt video file" error.
A config file with lines commented out using the wrong character. 行被错误的注释掉	Internally recognize most common comment prefixes, ignore them.	Terminate on startup with "bad configuration" error.
A user who enters dates in a strange format. 特殊的日期格式	Try parsing the string against a number of different date formats. Render the correct format back to the user.	Invalid date error.

"No Dashes Or Spaces"

- Credit card numbers are always printed and read aloud in groups of (usually) four digits.
- Computers are pretty good at text processing, so wasting the user's time by forcing them to retype their credit card numbers in strange formats is pure laziness on behalf of the developer.
- In Google Maps, you can enter just about *anything* in the search box and it will figure out a street address.

Pay My Bill | [Return to Bill Summary](#)

✓ Payment Type

2 Payment Details

Payment Frequency: AutoPayment

Step 2: Enter payment information

Method of Payment:

Credit Card

Name on Card:

Please enter the name on your card.

Card Number:

4111 1111 1111 1111

Please enter your card number.

Cardholder name

Cardholder name

Expiration date

Please enter numbers only.

Security code

CVC

[What's this?](#)

① Credit card number

4444 4444 4444 4



Billing ZIP code

ZIP

Comparison of Robustness and Correctness

- **Robustness makes life easier for users and third-party developers.**
 - By building in a bit of well thought-out flexibility, it's going to grant a second chance for users with clients that aren't quite compliant, instead of kicking them out cold.
- **Correctness, on the other hand, makes life easier for your developers.**
 - Instead of bogging down checking/fixing parameters and working around strange edge cases, they can focus on the one single model where all assumptions are guaranteed.
 - Any states outside the main success path can thus be ignored (by failing noisily) — producing code that is briefer, easier to understand, and easier to maintain.

Comparison of Robustness and Correctness

Internally, seek correctness;
Externally, seek robustness.

■ Externally and Internally:

- External interfaces (UI, input files, configuration, API etc) exist primarily to serve users and third parties. Make them robust, and as accommodating(乐于助人的) as possible, with the expectation that people will input garbage.
 - An application's **internal model** (i.e. domain model) should be as simple as possible, and always be in a 100% valid state. Use invariants and assertions to make safe assumptions, and just throw a big fat exception whenever you encounter anything that isn't right.
 - Protect the internal model from external interfaces with an anti-corruption layer which maps and corrects invalid input where possible, before passing it to the internal model. 采用隔离层来确保内部模型不受外部接口的干扰
- ## ■ Make your external interfaces robust, and make your internal model correct
- If you ignore users' needs, no one will want to use your software.
 - If you ignore programmers' needs, there won't be any software.

Comparison of Robustness and Correctness

- **Safety critical applications** tend to favor correctness to robustness.
 - It is better to return no result than to return a wrong result.
- **Consumer applications** tend to favor robustness to correctness.
 - Any result what so ever is usually better than the software shutting down.
- **Reliability**. The ability of a system to perform its required functions under stated conditions whenever required—having a long mean time between failures. 系统在任何需要的情况下在规定的条件下执行其所需功能的能力
- **Reliability=Robustness + Correctness**

Terms to denote software woes灾难

- An **error** is a wrong decision made during the development of a software system. (**error** \approx **mistake**)
- A **defect** is a property of a software system that may cause the system to depart from its intended behavior.
- A **fault**: wrong or missing function in the code. (**defect** \approx **fault**, **bug**)
- A **failure** is the manifestation of a fault during execution, is the event of a software system departing from its intended behavior during one of its executions.
- In general, **error** \rightarrow **defect/fault/bug** \rightarrow **failure**

Error → Fault → Failure

- The **error**: write “+” to “-”
- The **fault/defect/bug**: the wrong result of statement.
- The execution will show a **failure**.

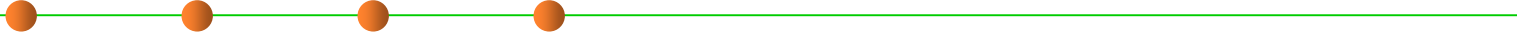
```
value1 = 5;  
value2 = 3;  
ans = value1 - value2;  
printf("The addition of 5 + 3 = %d.", ans);
```

- A programmer makes **an error (mistake)**, which results in a **defect (fault, bug)** in the software source code.
- If this defect is executed, in certain situations the system will produce wrong results, causing a **failure**.

Error → Fault → Failure

- **Not all software defects are caused by coding errors.**
 - One common source of expensive defects is **requirement gaps**, e.g., unrecognized requirements which result in errors of omission by the program designer. Requirement gaps can often be non-functional requirements.并非所有的软件缺陷都是由编码错误引起的,例如:遗漏需求等。
- **Not all defects will necessarily result in failures.**并非所有的缺陷都必然会导致失败
 - For example, defects in dead code will never result in failures.
- **A defect can turn into a failure when the environment is changed.**
 - Examples of these changes in environment include the software being run on a new computer hardware platform, alterations in source data, or interacting with different software.
- **A single defect may result in a wide range of failure symptoms.**单个缺陷可能导致各种各样的失败现象。

Steps for improving robustness and correctness

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- **Step 0: To program code with robustness and correctness objectives (Assertions, defensive programming, code review, formal validation, etc)**
 - **Step 1: To observe failure symptoms (Memory dump, stack traces, execution logs, testing)**
 - **Step 2: To identify potential fault (bug localization, debug)**
 - **Step 3: To fix errors (code revision)**



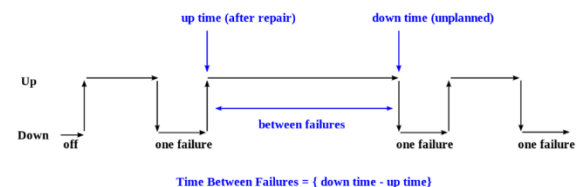
2 How to measure robustness and correctness?



Mean time between failures (MTBF)

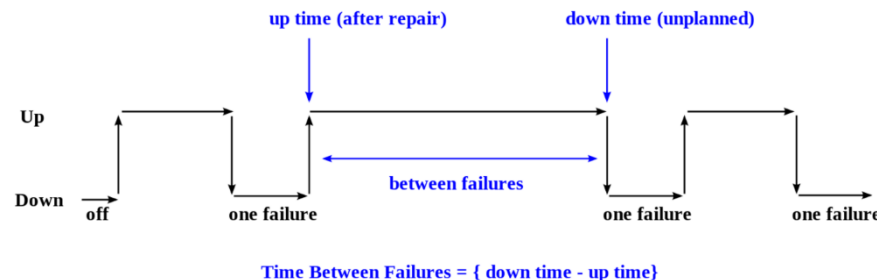
- **Mean time between failures (MTBF)** is the predicted elapsed time between inherent failures of a system during operation. 平均故障间隔时间，是指相邻两次故障之间的平均工作时间。
- MTBF is calculated as the arithmetic mean (average) time between failures of a system.
- The definition of MTBF depends on the definition of what is considered a system failure. **MTBF的计算依赖于系统failure的定义**
 - For complex, repairable systems, failures are considered to be those out of design conditions which place the system out of service and into a state for repair. 导致系统不可使用的**failure**
 - Failures which occur that can be left or maintained in an unrepaired condition, and do not place the system out of service, are not considered failures under this definition. 出现**failure**，但系统仍可运行

$$\text{MTBF} = \frac{\sum (\text{start of downtime} - \text{start of uptime})}{\text{number of failures}}$$



Mean time between failures (MTBF)

- **Mean time between failures (MTBF)** is used for **reparable systems**, while **mean time to failure (MTTF)** denotes the expected time to failure for a **non-reparable system**. **MTTF描述不可修复系统的平均失效前时间**
- $MTTF = \Sigma t_i / \Sigma r_i$
 - t_i : 在发生所有故障之前的工作时间, r_i : 故障发生次数
 - For example, three identical systems starting to function properly at time 0 are working until all of them fail. The first system failed at 100 hours, the second failed at 120 hours and the third failed at 130 hours.
 - The MTBF of the system is the average of the three failure times, which is 116.667 hours. If the systems are non-reparable, then their MTTF would be 116.667 hours.



Residual defect rates

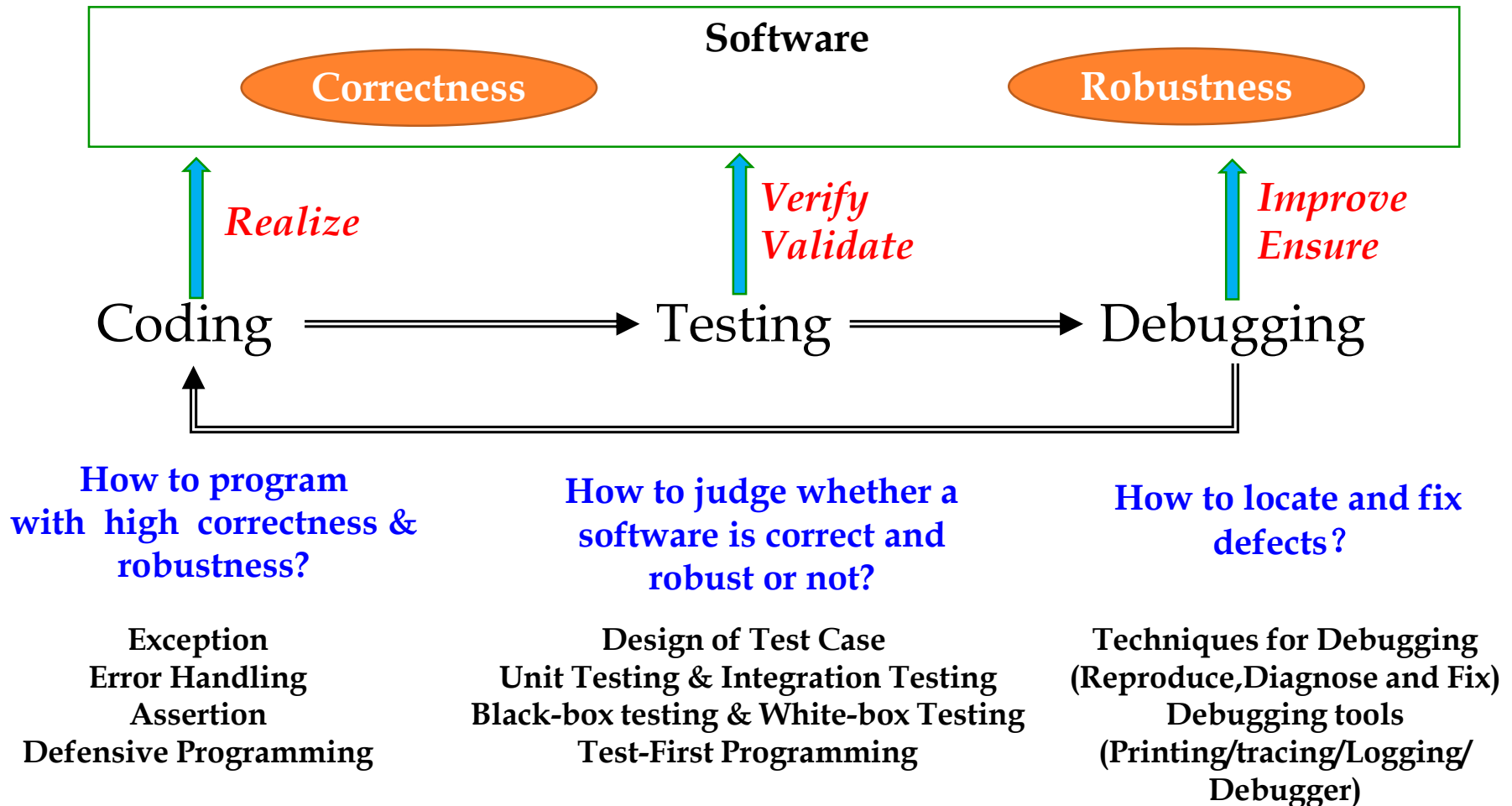
- **Residual defect rates** refers to “bugs left over after the software has shipped” per KLOC(千行代码):
 - 1 - 10 defects/kloc: **Typical industry software.**
 - 0.1 - 1 defects/kloc: **High-quality validation.** The Java libraries might achieve this level of correctness.
 - 0.01 - 0.1 defects/kloc: **The very best, safety-critical validation.** NASA and companies like Praxis can achieve this level.
- **This can be discouraging for large systems.** For example, if you have shipped a million lines of typical industry source code (1 defect/kloc), it means you missed 1000 bugs!



3 Objectives of this chapter



Objectives of this chapter





The end

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