



1 Views and Quality Objectives of Software Construction

软件构造的多维度视图和质量目标



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Objective of this lecture

- To understand the constituents of a software system in three orthogonal dimensions
从三个维度看软件系统的构成
- To know what models are used to describe the morphology and states of a software system
用什么样的模型/视图描述软件系统
- To treat software construction as the transformations between different views
将“软件构造”看作“不同视图之间的转换”

首先要搞清楚：软件构造的对象是什么、如何刻画
然后再关注：如何构造

Objective of this lecture

- To know quality factors to be cared in software construction
软件构造过程中应考虑的重要质量指标
- To understand the consequences if quality objectives cannot be achieved
如果达不到期望的质量目标，会有什么后果
- To know what construction techniques are to be studied for each quality factor in this course
有哪些面向质量指标的软件构造技术

除了要搞清楚“要构造的结果是什么”
还要理解清楚“构造的结果如何才算好”

Outline

Outline

- 
- **Quality properties of software systems**
 - External vs. internal quality factors
 - Important external quality factors
 - Tradeoff between quality factors
 - **Five key quality objectives of software construction**
 - **Easy to understand:** elegant and beautiful code / understandability
 - **Ready for change:** maintainability and adaptability
 - **Cheap for develop:** design for/with reuse: reusability
 - **Safe from bugs:** robustness
 - **Efficient to run:** performance
 - **Summary**

Reading

- MIT 6.031: Getting started, readings 02
- CMU 17-214: Aug 29
- 代码大全: 第1-4章
- Object-Oriented Software Construction: 第1章
- 代码大全: 第20章
- 软件工程--实践者的研究方法: 第14章

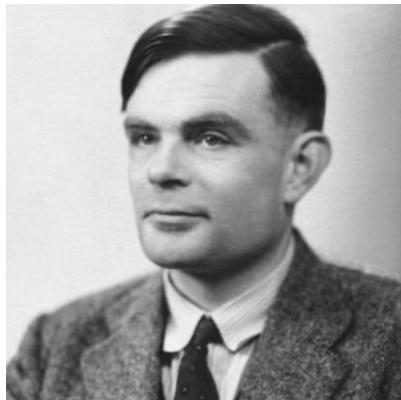




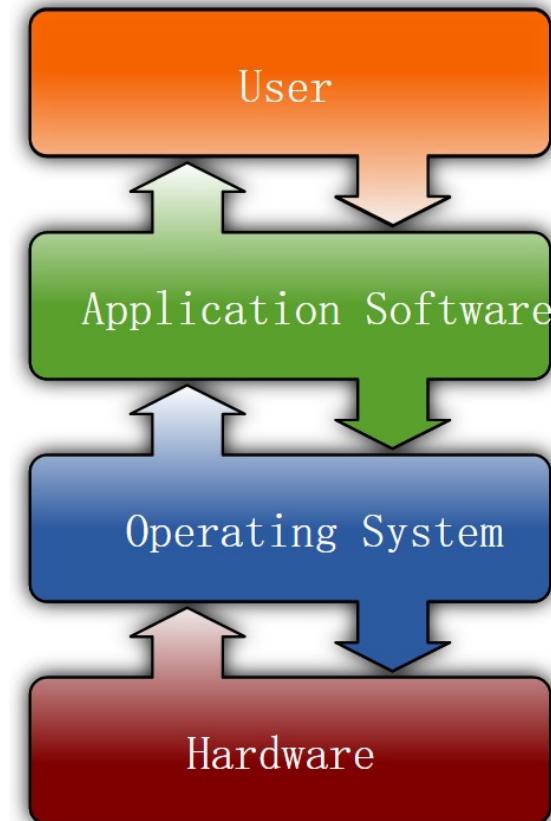
1 Multi-dimensional software views

What is a Software?

- The term “software” was firstly proposed by **Alan Turing**.
 - System software vs. Application software
 - Desktop/web/mobile/embedded software
 - Business/personal-oriented software
 - Open source vs. proprietary software



Alan Turing (1912-1954)



Constituents of a software system

- Software = Program (codes)?
- Software = Algorithms + Data Structure?
- Software = Program + Data + Documents
- Software = Modules (Components) + Data/Control Flows



Donald E. Knuth (1938-)
Turing Award 1974

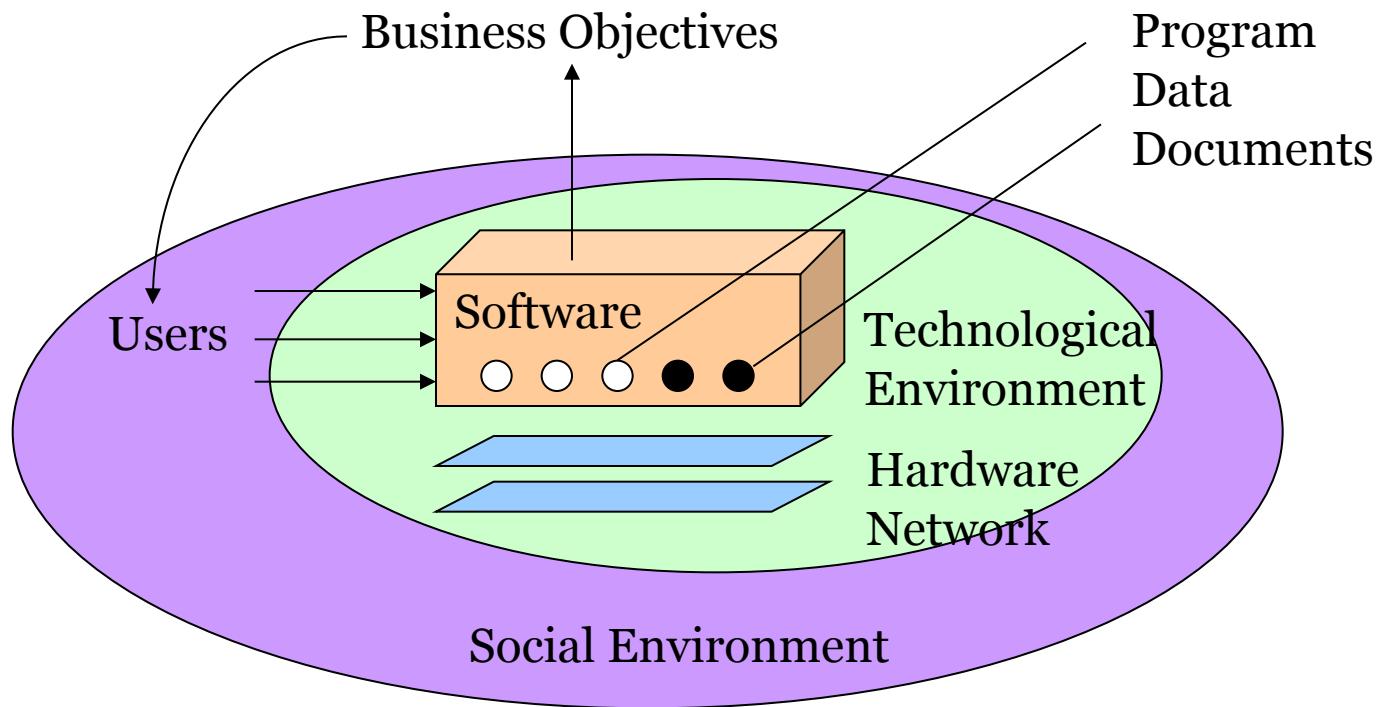


Edsger Dijkstra (1930-2002)
Turing Award 1972

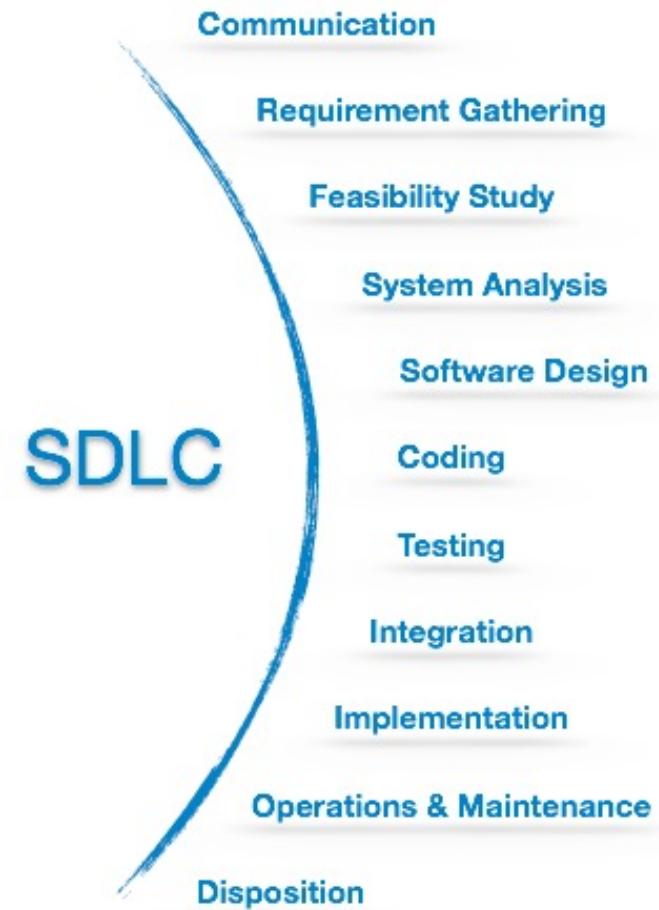
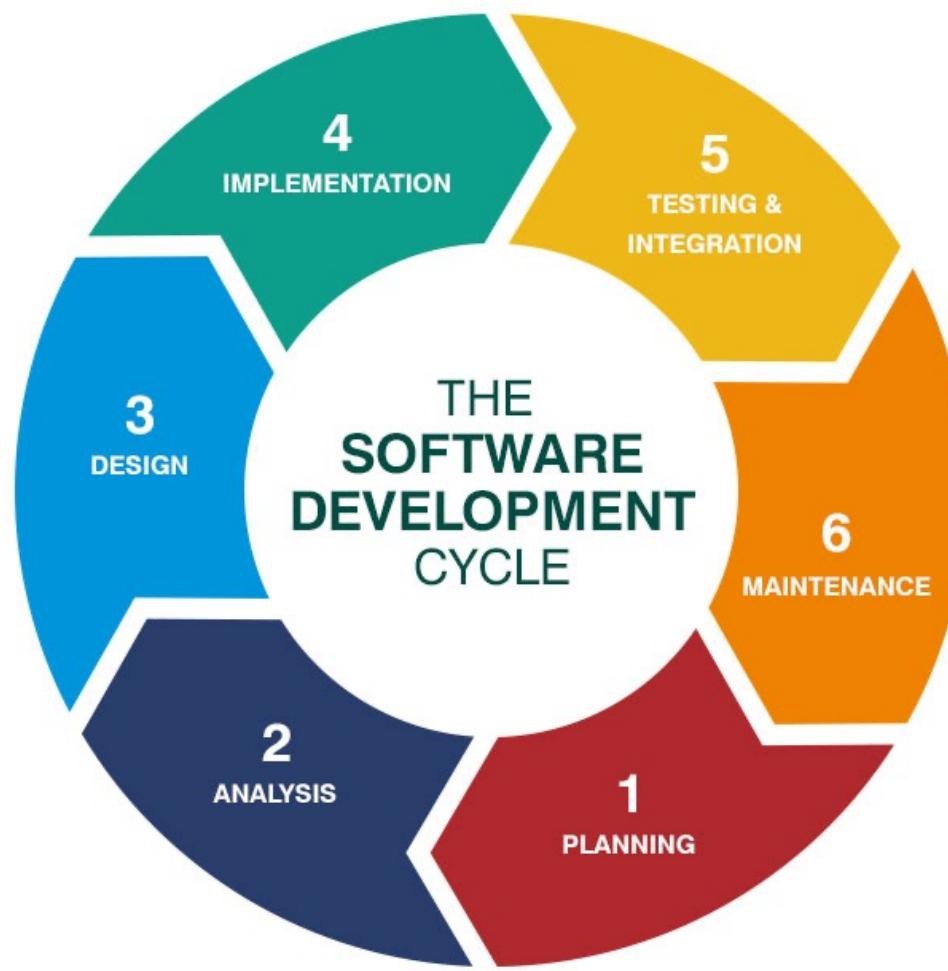


Niklaus Wirth (1934-)
Turing Award 1984

Constituents of a software system: one more step



Constituents of a software system: two more steps



Multi-dimensional software views



	Moment	Period		
	Code-level	Component-level	Code-level	Component-level
Build-time	Source code, AST, Interface-Class- Attribute- Method (Class Diagram)	Package, File, Static Linking, Library, Test Case, Build Script (Component Diagram)	Code Churn	Configuration Item, Version
Run-time	Code Snapshot, Memory dump	Package, Library, Dynamic linking, Configuration, Database, Middleware, Network,	Execution stack trace, Concurrent multi- threads	Event log, Multi-processes, Distributed processes



(1) Build-time Views



Build-time views of a software system

- Build-time (构造阶段): idea \Rightarrow requirement \Rightarrow design \Rightarrow code \Rightarrow installable / executable package
 - Code-level view: source code ---- how source code are logically organized by basic program blocks such as functions, classes, methods, interfaces, etc, and the dependencies among them 代码的逻辑组织
 - Component-level view: architecture ---- how source code are physically organized by files, directories, packages, libraries, and the dependencies among them 代码的物理组织

- Moment view: what do source code and component look like in a specific time 特定时刻的软件形态
- Period view: how do they evolve/change along with time 软件形态随时间的变化

(1) Build-time, moment, and code-level view

- How source code are **logically organized** by basic program blocks such as **functions, classes, methods, interfaces, etc**, and the dependencies among them.
- Three inter-related forms:
 - **词汇层面**: Lexical-oriented source code
 - **语法层面**: Syntax-oriented program structure: e.g., Abstract Syntax Tree (AST)
 - **语义层面**: Semantics-oriented program structure: e.g., Class Diagram

Lexical-based semi-structured source code

- Source code: the most important assets in software development

```
01 // First, log in
02 LoginResult loginResult=null;
03 SoapBindingStub sfdc=null;
04 sfdc = (SoapBindingStub) new SforceServiceLocator().getSoap();
05 // login
06 loginResult = sfdc.login("username","password");
07
08 // The set up some security related items
09 // Reset the SOAP endpoint to the returned server URL
10 sfdc._setProperty(SoapBindingStub.ENDPOINT_ADDRESS_PROPERTY,loginResult.getServerUrl());
11 // Create a new session header object
12 // add the session ID returned from the login
13 SessionHeader sh=new SessionHeader();
14 sh.setSessionId(loginResult.getSessionId());
15 sfdc.setHeader(new SforceServiceLocator().getServiceName().getNamespaceURI(),
16 "SessionHeader",sh);
17
18 // now that we're logged in, make some calls
19 GetUserInfoResult userInfo = sfdc.getUs
20
21 // create a new account object local
22 Account account = new Account()
23 account.setAccountNumber("002P00000000000")
24 account.setName("My New Account")
25 account.setBillingCity("Glasg
26
27
28 SObject[] sObjects = new SObject[]
29 sObjects[0] = account;
30
31 // persist the object
32 SaveResult[] saveResults = sfdc.create(sObjects)
```

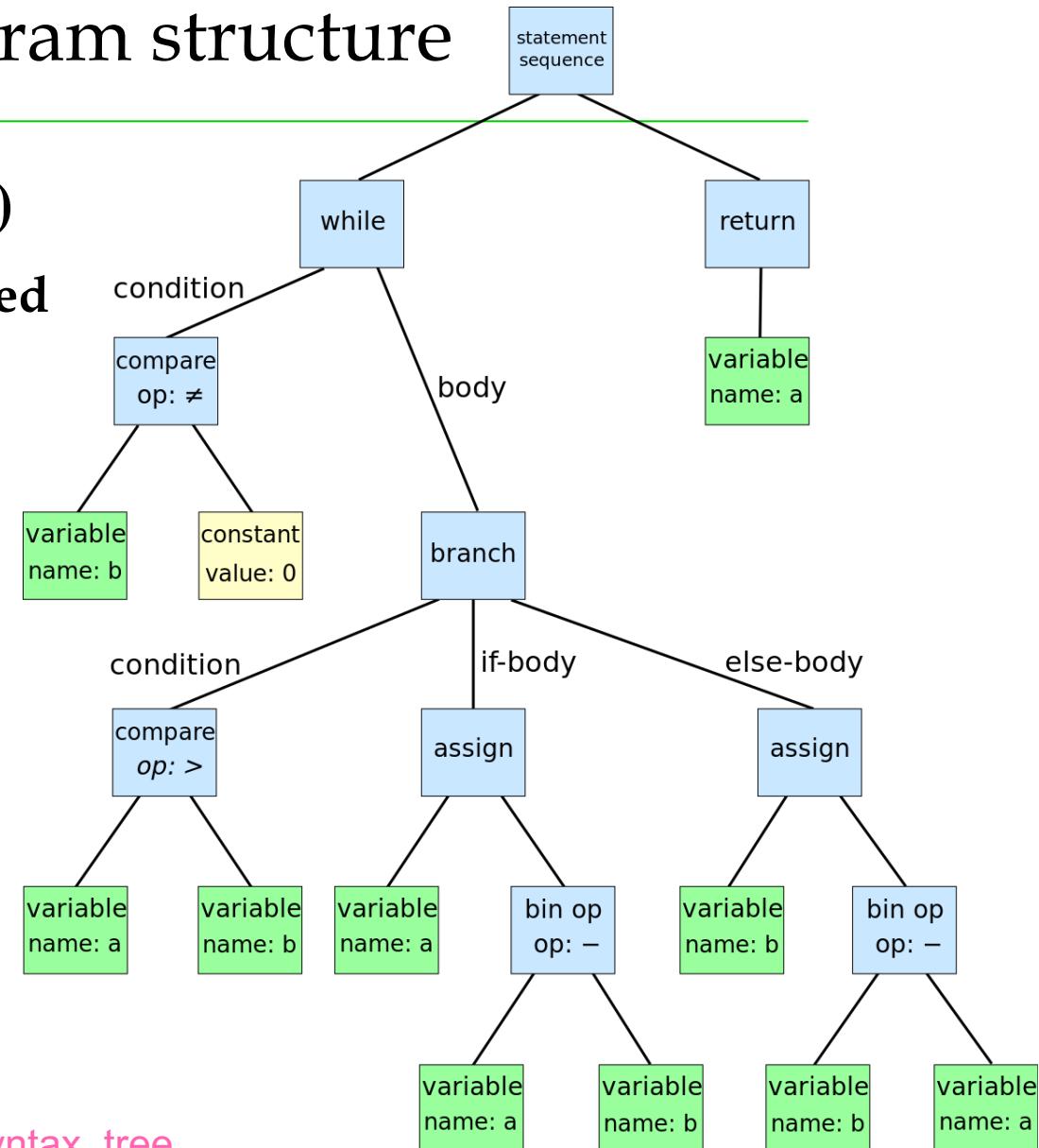
半结构化：近乎自然语言的
风格+遵循特定的编程语法

前者：方便程序员
后者：方便编译器

Syntax-oriented program structure

- Abstract Syntax Tree (AST)
- To represent semi-structured source code as a structured tree.

```
while (a != b) {
    if (a > b)
        a = a - b;
    else
        b = b - a;
}
return a;
```



Processing Java Source Files by AST

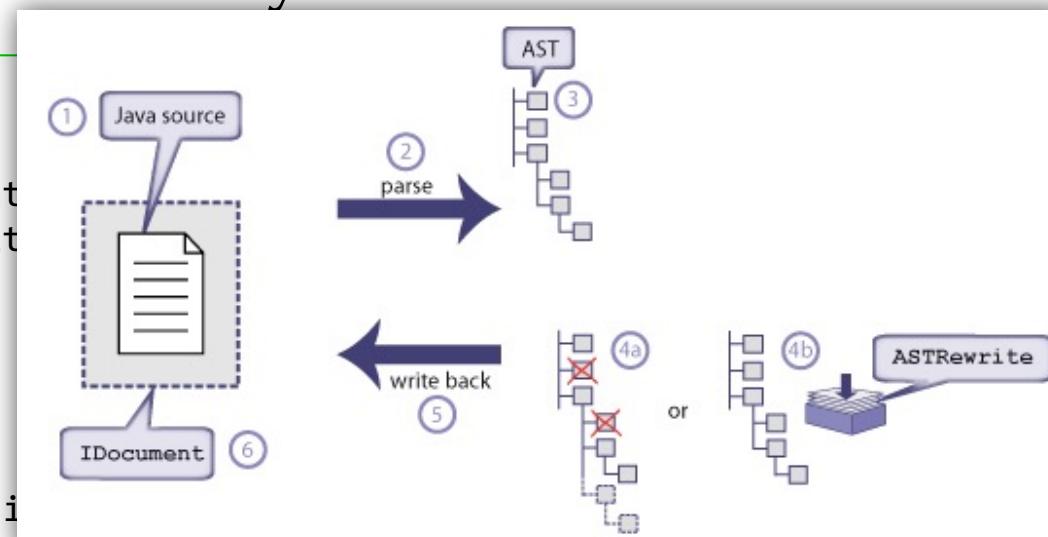
```

import org.eclipse.jdt.core.dom.*;
import org.eclipse.jface.text.Document
import org.eclipse.text.edits.TextEdit

public class AST {
    void processJavaFileByAST(){
        Document doc = new Document(javaFi
        ASTParser parser = ASTParser.newParser(AST.JLS5),
        parser.setResolveBindings(true);
        parser.setSource(doc.get().toCharArray());
        CompilationUnit cu = (CompilationUnit) parser.createAST(null);
        cu.recordModifications();

        AST ast = cu.getAST();
        ImportDeclaration id = ast.newImportDecl
        id.setName(ast newName(new String[] {"i
        cu.imports().add(id); // add import decl
        TextEdit edits = cu.rewrite(doc, null);
    }
}

```



AST: 彻底结构化，将源代码变为一棵树，对树做各种操作==对源代码的修改

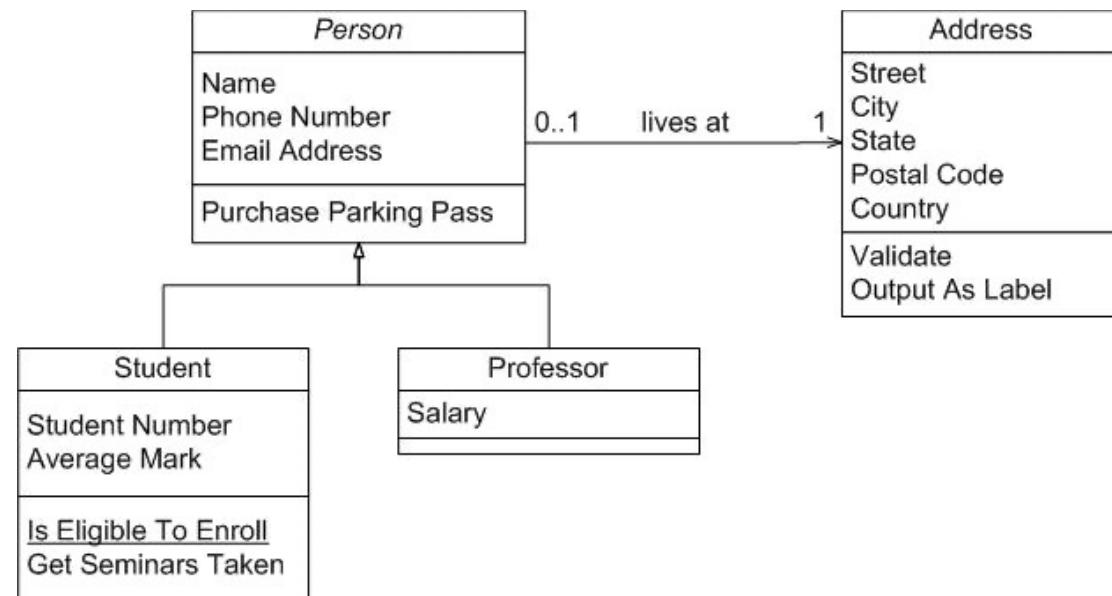
Semantics-oriented program structure

- E.g., using Class Diagram (UML) to describe interfaces, classes, attributes, methods, and relationships among them.
- Graphics-based or formally defined. 通常是图形化或形式化的
- Modeled in design phase, and transformed into source code.
- It is the result of Object-Oriented Analysis and Design in terms of user requirements.

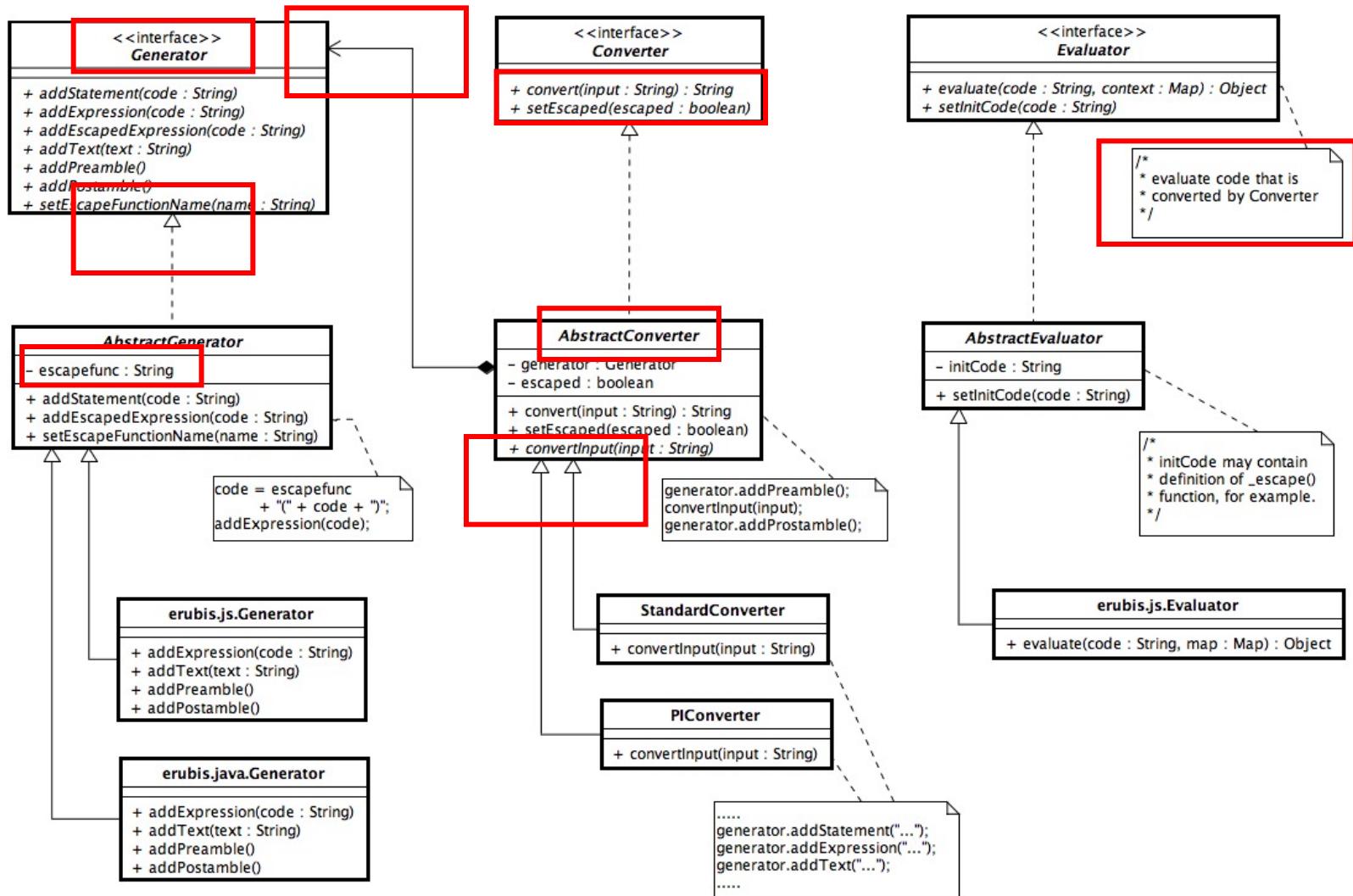
语义：源代码具体想实现什么目标？

源代码---现实世界

用于表达“需求”
和“设计”思想，
再转化成code



Semantics-oriented program structure



(2) Build-time, period, and code-level view

- Views describing “**changes**” along with time.
- Code churn 代码变化:** Lines added, modified or deleted to a file from one version to another.

Code Before

```
int i = n;
while (i--)
    printf ("%d", i);
```

Code After

```
//print n integers iff n≥ 0
int i = n;
while (--i > 0)
    printf ("%d", i);
```

two lines added

Code Before

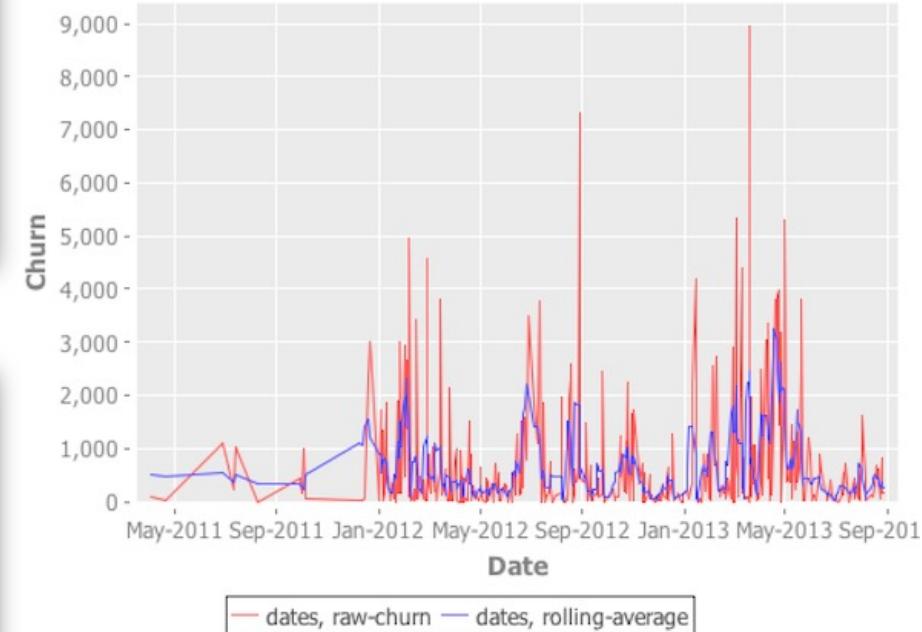
```
int i = n;
while (i--)
    printf ("%d", i);
```

Code After

```
//print n integers iff n≥ 0
int i = n;
while (--i > 0)
    printf ("%d", i);
```

one line deleted

Churn Trends



Code churn

Code churn is defined as lines added, modified or deleted to a file from one version to another.

Event: Add radio click triggering tests

Ref b442aba
Ref gh-3423

master

 alexr101 committed with gibson042 13 days ago 1 parent b442aba commit 5f35b5b406ae7d504de86a3f0a5647b2fdf4f2af

Showing 1 changed file with 26 additions and 11 deletions.

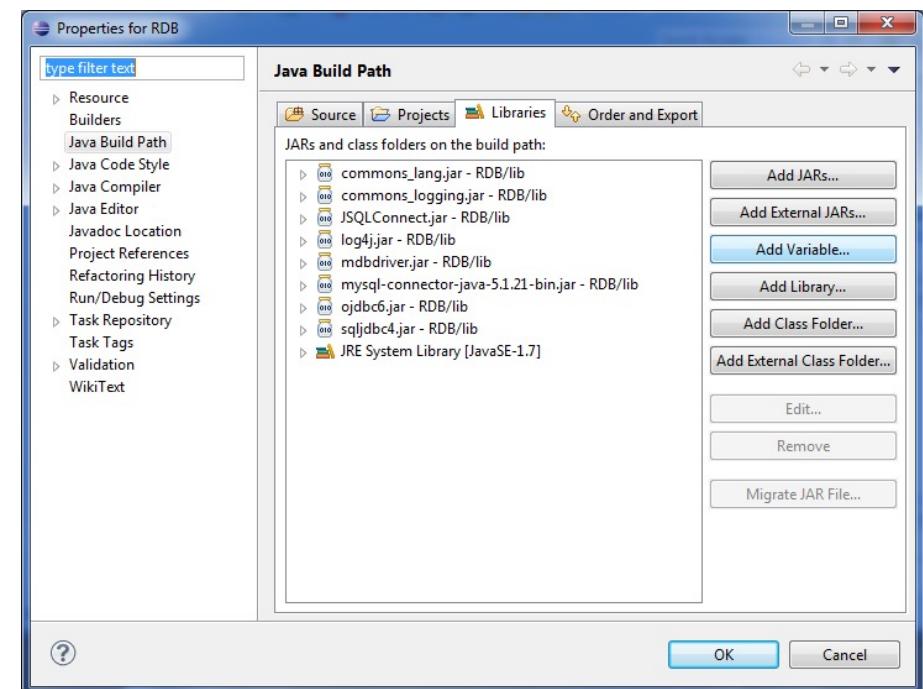
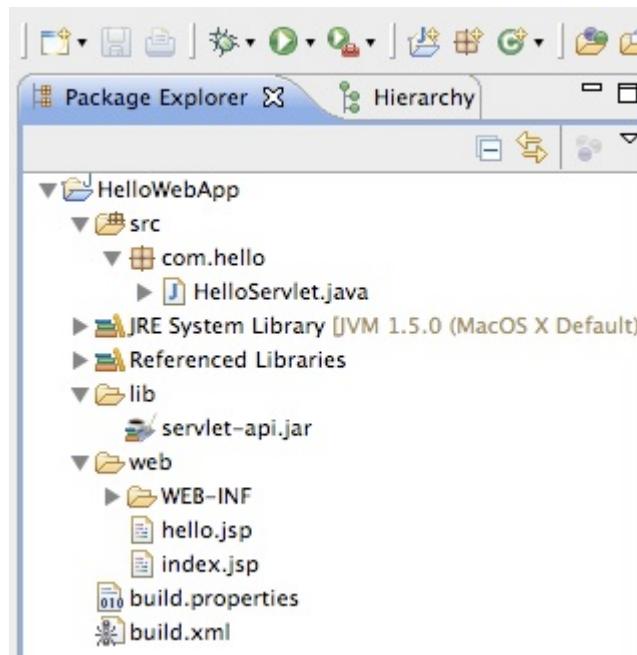
Unified Split

37 test/unit/event.js View

```
@@ -2364,33 +2364,48 @@ QUnit.test( "clone() delegated events (#11076)", function( assert ) {  
2364 2364     clone.remove();  
2365 2365 } );  
2366 2366  
2367 -QUnit.test( "checkbox state (#3827)", function( assert ) {  
2368 -    assert.expect( 9 );  
2367 +QUnit.test( "checkbox state (#3827, gh-3423)", function( assert ) {  
2368 +    assert.expect( 17 );  
2369 2369  
2370 -    var markup = jQuery( "<div><input type=checkbox></div>" ).appendTo( "#qunit-fixture" ),  
2371 -        cb = markup.find( "input" )[ 0 ];  
2370 +    var cbParent = jQuery( "<div><input type=checkbox></div>" ).appendTo( "#qunit-fixture" ),  
2371 +        cb = cbParent.find( "input" )[ 0 ],  
2372 +        radioParent = jQuery(  
2373 +            "<div><input type=radio name=gh3423><input type=radio name=gh3423></div>"  
2374 +            ).appendTo( "#qunit-fixture" ),  
2375 +        radio = radioParent.find( "input" )[ 0 ],  
2376 +        radio2 = radioParent.find( "input" )[ 1 ];  
2372 2377
```

(3) Build-time, moment, and component-level view

- Source code are physically organized into **files** which further are organized by **directories**;
- **Files** are encapsulated into **packages** and, logically, **components** and **sub-systems**.
- Reusable modules are in the form of **libraries**.



Library

- **Libraries** are stored in **disk files** of their own, collect a set of code functions that can be **reused** across a variety of programs.
 - Developers aren't always building a single executable program file, but join **custom-developed software** and **prebuilt libraries** into a single program.
- In **build-time**, a library function can be viewed as an extension to the standard language and is used in the same way as functions written by the developers. **开发者像使用编程语言指令一样使用库中的功能**

```
System.out.println("Hello World");
```
- **Sources of libraries:**
 - From OS pre-installed set of libraries for operations such as file and network I/O, GUI, mathematics, database assess; **操作系统提供的库**
 - From language SDK; **编程语言提供的库**
 - From third-party sources; **第三方公司提供的库**
 - Developers can also publish their own libraries. **你自己积累的库**

Maven Repository

MVNREPOSITORY

Indexed Artifacts (8.54M)

The chart shows a steady increase in indexed artifacts over time, starting around 2004 with approximately 42,650 artifacts and reaching about 853,100 by 2018.

What's New in Maven

- Ardulink Core Base** (org.ardulink > ardulink-core-base > 2.1.0) - 14 usages, Apache. Last Release on Jan 13, 2018.
- Gmail API V1 Rev78 1.23.0** (com.google.apis > google-api-services-gmail > v1-rev78-1.18...) - 7 usages, Apache. Last Release on Jan 14, 2018.
- Gmail API V1 Rev78 1.23.0** (com.google.apis > google-api-services-gmail > v1-rev78-1.21.0) - 7 usages, Apache. Last Release on Jan 14, 2018.
- Gmail API V1 Rev78 1.23.0** (com.google.apis > google-api-services-gmail > v1-rev78-1.22.0) - 7 usages, Apache. Last Release on Jan 14, 2018.

Popular Categories

- Aspect Oriented
- Actor Frameworks
- Application Metrics
- Build Tools
- Bytecode Libraries
- Command Line Parsers
- Cache Implementations
- Cloud Computing
- Code Analyzers
- Collections
- Configuration Libraries
- Core Utilities
- Date and Time Utilities

```
<dependency>
    <groupId>junit</groupId>
    <artifactId>junit</artifactId>
    <version>4.12</version>
    <scope>test</scope>
</dependency>
```

Home » junit » junit

JUnit

JUnit is a unit testing framework for Java, created by Erich Gamma and Kent Beck.

License	EPL 1.0
Categories	Testing Frameworks
Tags	testing junit
Used By	64,350 artifacts

Central (24) Redhat GA (3) JBoss 3rd-party (1) Alfresco Public (1)

	Version	Repository	Usages	Date
4.12.x	4.12	Central	25,546	(Dec, 2014)
	4.12-beta-3	Central	28	(Nov, 2014)
	4.12-beta-2	Central	31	(Sep, 2014)
	4.12-beta-1	Central	31	(Jul, 2014)
4.11.x	4.11	Central	20,089	(Nov, 2012)
	4.11-beta-1	Central	22	(Oct, 2012)
4.10.x	4.10	Central	7,882	(Sep, 2011)
4.9.x	4.9	Central	1,096	(Aug, 2011)
	4.8.2	Central	4,969	(Oct, 2010)
4.8.x	4.8.1	Central	4,548	(Feb, 2010)
	4.8	Central	254	(Oct, 2010)
4.7.x	4.7	Central	1,912	(Aug, 2009)
4.6.x	4.6	Central	720	(May, 2009)
4.5.x	4.5	Central	1,557	(Sep, 2008)
4.4.x	4.4	Central	2,273	(Aug, 2007)

Linking with a library

- When a program is edited, built and installed, a list of libraries to search must be provided. 编程时和build时，需告诉IDE和JVM在哪里寻找某些库
- If a function is referenced in the source code but the developer didn't explicitly write it, the list of libraries is searched to locate the required function.

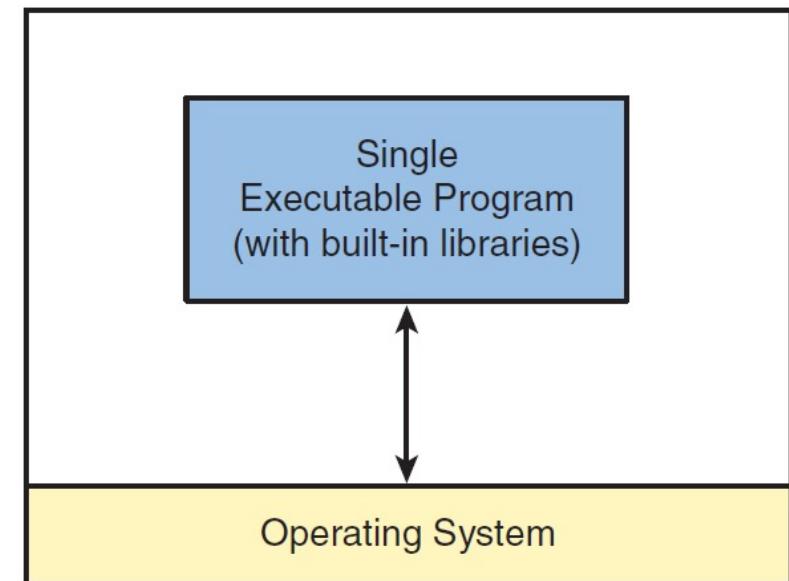
```
javac -classpath ./lib/*.jar
```

- When the function is found, the appropriate object file is copied into the executable program.
- Two different approaches of integrating a library into an executable program:
 - Static linking (静态链接)
 - Dynamic linking (动态链接)

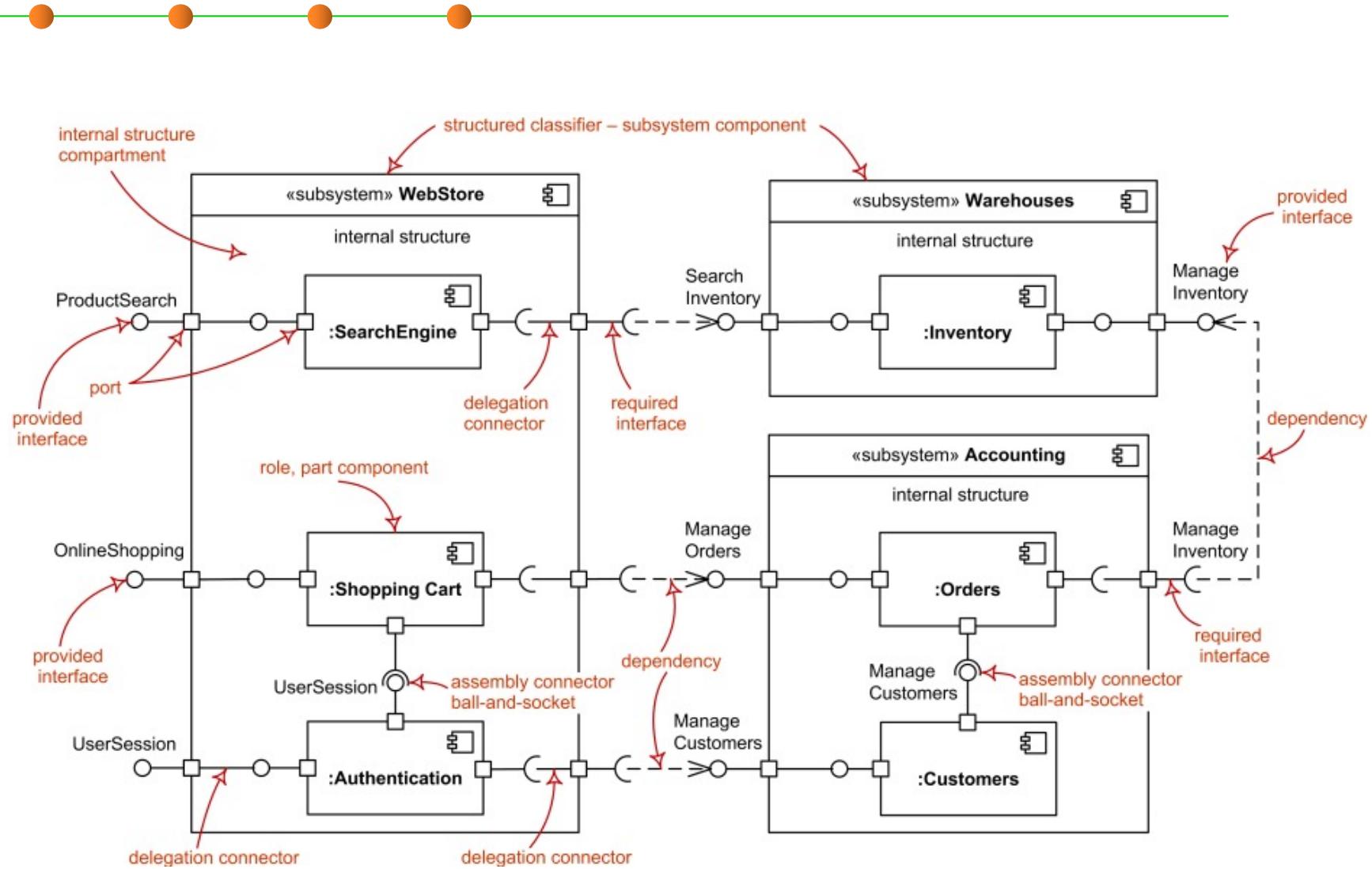
Static linking

- In static linking, a library is a collection of individual object files.
- During the build process, when the linker tool determines that a function is required, it extracts the appropriate object file from the library and copies it into the executable program
 - 库被拷贝进入代码形成整体，执行的时候无需提供库文件
 - The library's object file appears identical to any of the object files the developer created on his or her own.
- Static linking happens in **build time**
 - End up with a single executable program to be loaded onto the target machine.
 - After the final executable program has been created, it's impossible to separate the program from its libraries.

静态链接发生在构造阶段

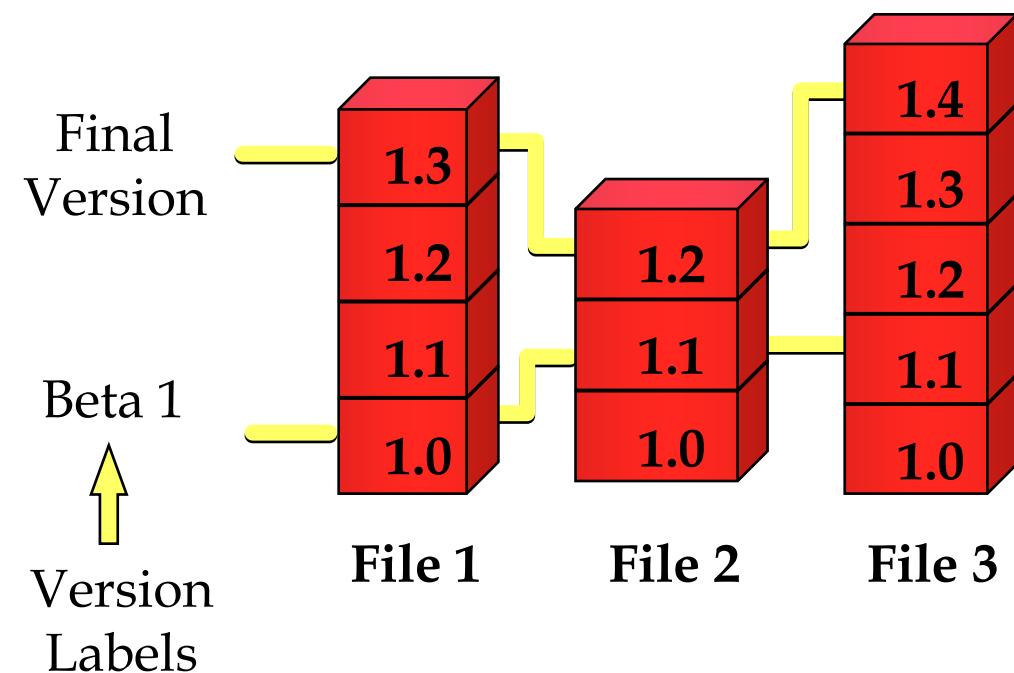
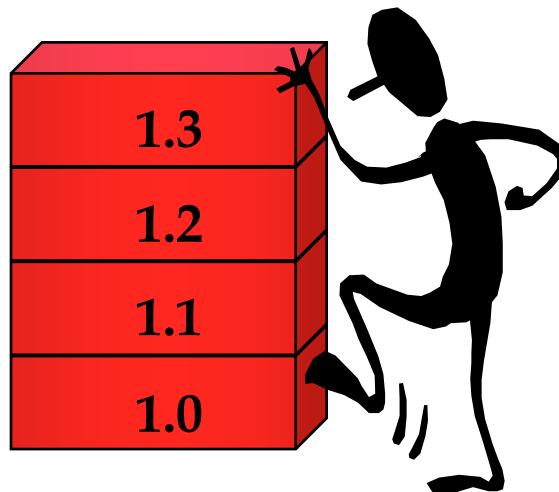


Component diagram in UML

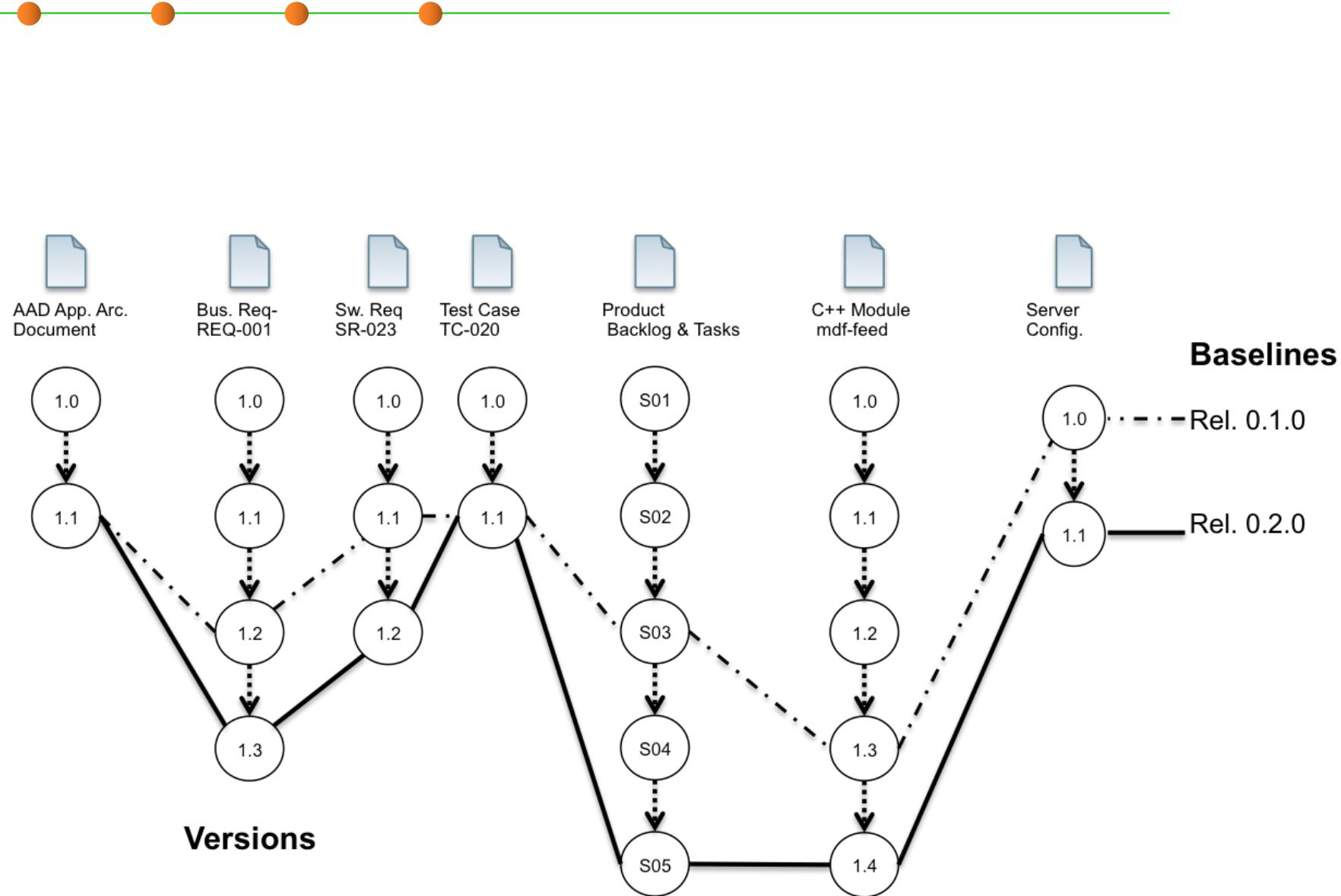


(4) Build-time, period, and component-level view

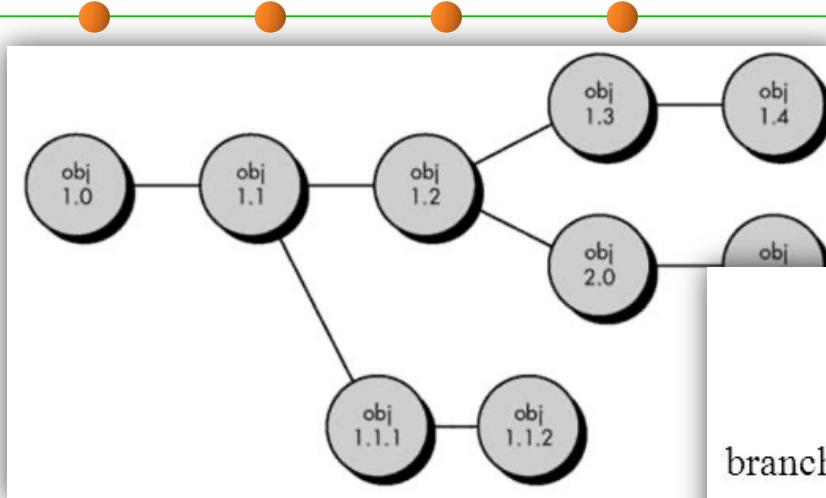
- How do all files/packages/components/libraries change in a software system along with time? 各项软件实体随时间如何变化?
- Software Configuration Item (SCI, 配置项)
- Version (版本)



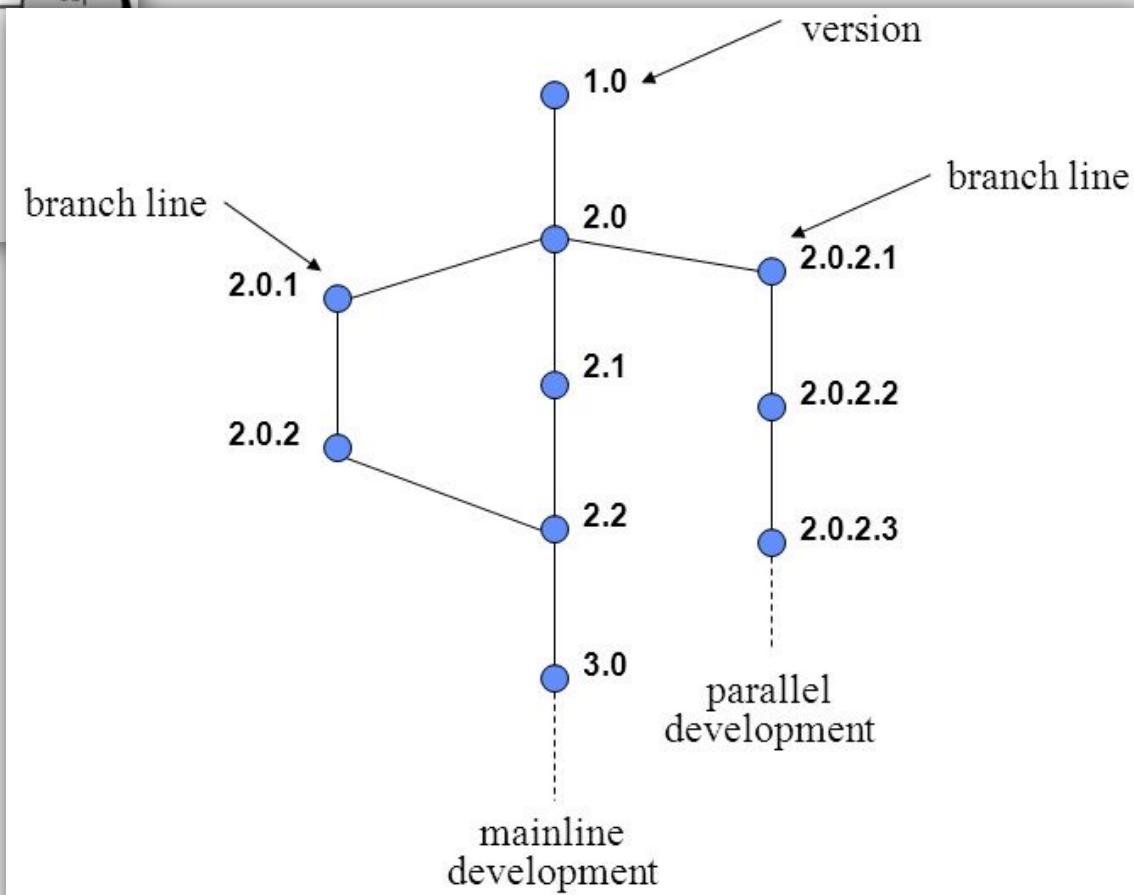
Version Control System (VCS)



Evolution Graph (of a SCI or a Software)

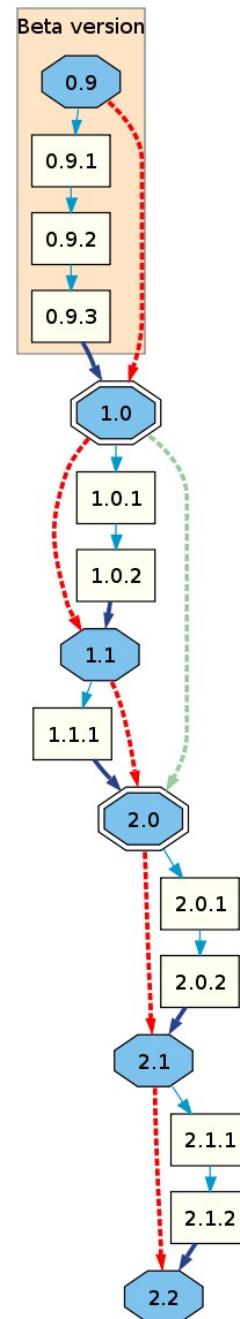
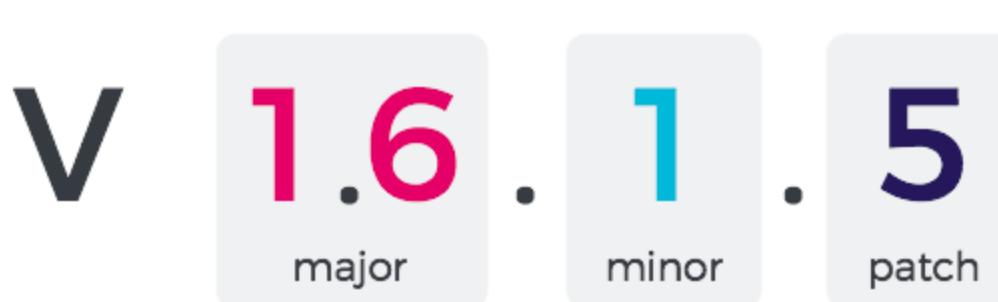


Evaluation graph describes the development process and phases of a software.



Versioning

- **Software versioning** is the process of assigning either unique version names or unique version numbers to unique states of computer software.
 - Within a given version number category (major, minor), these numbers are generally assigned in increasing order and correspond to new developments in the software.
 - At a fine-grained level, revision control is often used for keeping track of incrementally different versions of electronic information, whether or not this information is computer-based.





(2) Runtime Views



Runtime views of a software system

- **Runtime:** what does a program look like when it runs inside the target machine, and what are all the disk files that the target machine needs to load into memory? **运行时：**程序被载入目标机器，开始执行
 - **Code-level view:** source code ---- what do the **in-memory states** of an executable program look like and how do program units (objects, functions, etc) interact with each other? **代码层面：**逻辑实体在内存中如何呈现?
 - **Component-level view:** architecture ---- how are software packages deployed into **physical environment** (OS, network, hardware, etc) and how do they interact? **构件层面：**物理实体在物理硬件环境中如何呈现?
- **Moment view:** how do programs behave **in a specific time** **逻辑/物理实体在内存/硬件环境中特定时刻的形态如何?**
- **Period view:** how do they behave **along with time** **逻辑/物理实体在内存/硬件环境中的形态随时间如何变化?**

High-level concepts of run-time software

- **Executable programs:** The sequence of machine-readable instructions that the CPU executes, along with associated data values.
 - This is the fully compiled program that's ready to be loaded into the computer's memory and executed.

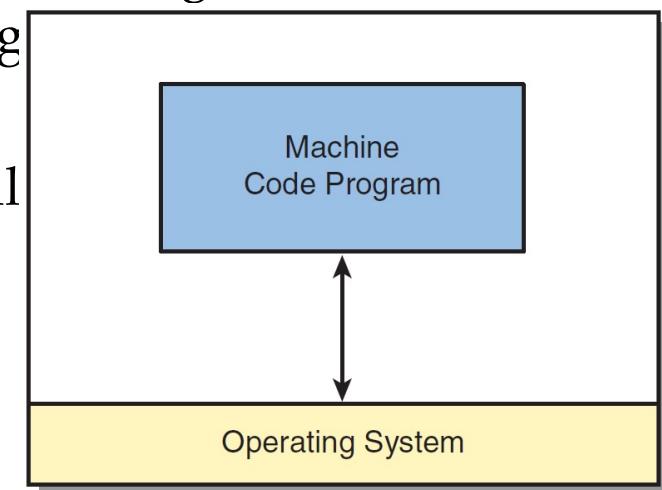
- **Libraries:** Collections of commonly used object code that can be reused by different programs.
 - Most operating systems include a standard set of libraries that developers can reuse, instead of requiring each program to provide their own.
 - A library can't be directly loaded and executed on the target machine; it must first be linked with an executable program.

High-level concepts of run-time software

- Configuration and data files: These are not executable files; they provide useful data and configuration information that the program can load from disk.
- Distributed programs: This type of software consists of multiple executable programs that communicate with each other across a network or simply as multiple processes running on the same machine.
 - This contrasts with more traditional software that has a single monolithic program image.

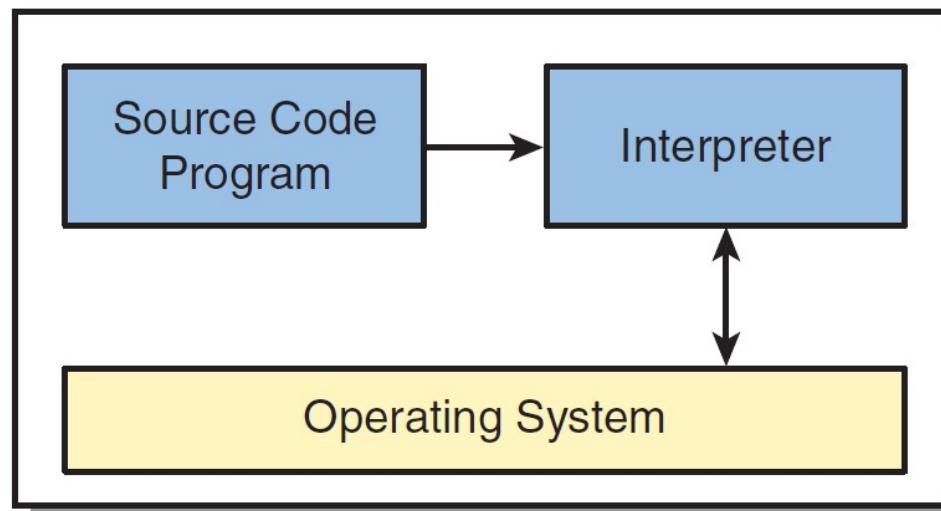
Executable Programs: Native Machine Code

- A program is loaded into memory first, and several mechanisms exist for executing the software, depending on how much compilation took place before the program was loaded and how much OS supports the program requires.
- **Native Machine Code (原生机器码):**
 - Fully converted executable program into the CPU's native machine code.
 - The CPU simply “jumps” to the program's starting location, and all the execution is performed purely using CPU's hardware.
 - While it's executing, the program optionally makes calls into the operating system to access files and other system resources.
 - This is the **fastest** way to execute code, because the program fully accesses to the CPU's features.



Executable Programs: Full Interpretation

- **Full Program Interpretation (程序完全解释执行):**
 - The runtime system loads the entire source code into memory and interprets it (such as BASIC, UNIX shell, etc)

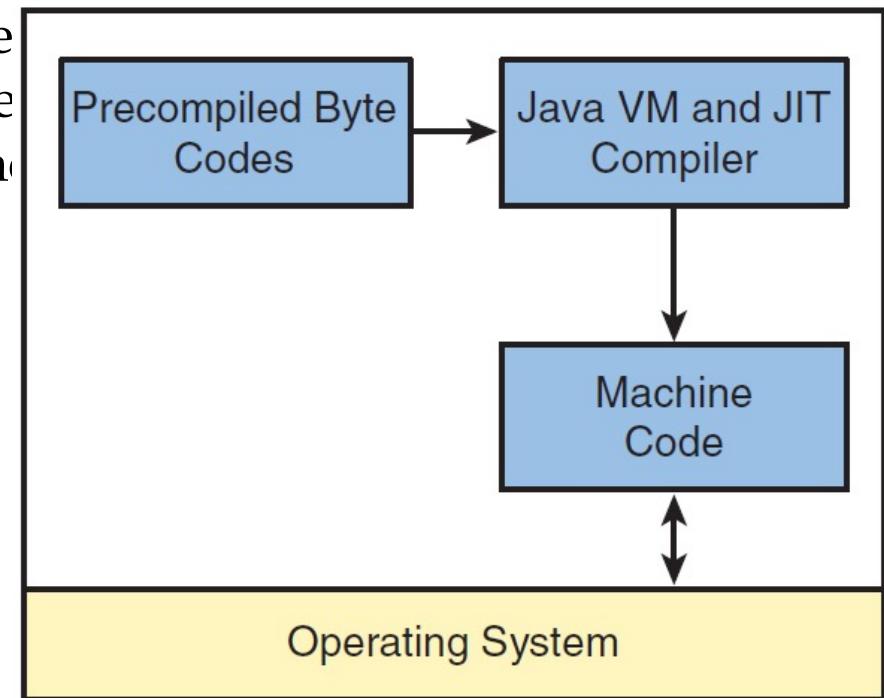


Executable Programs: Interpreted Byte Codes

- **Interpreted Byte Codes (解释型字节码):**

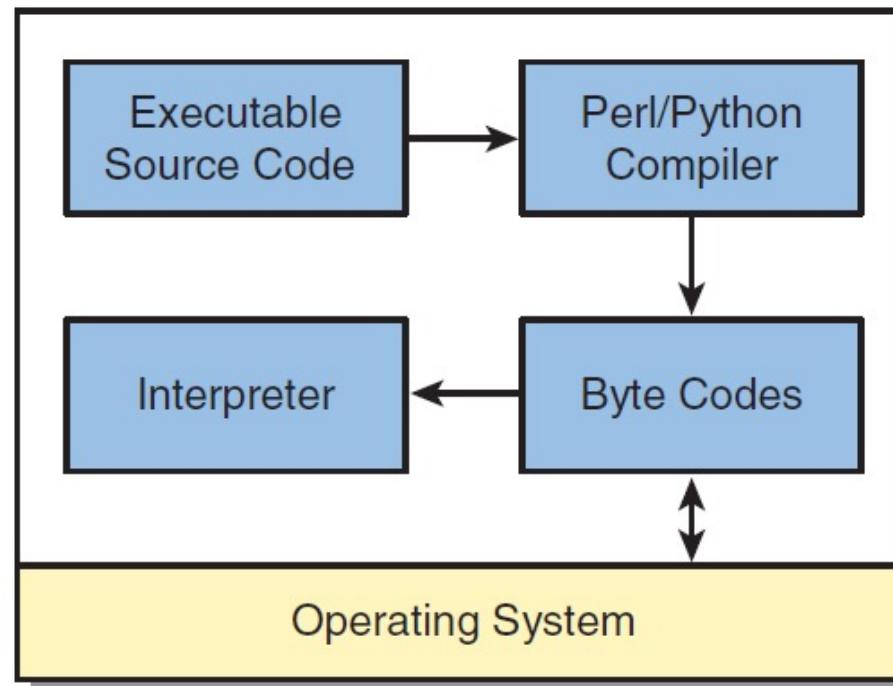
- Byte codes are similar to native machine code, except that the CPU doesn't directly understand them.
- It first translates them into native machine code or interprets them as the program executes.
- A byte code environment therefore requires that an additional interpreter or compiler be loaded alongside the program.

- **Java Virtual Machine (JVM)**



Executable Programs: Interpreted Byte Codes

- **Perl or Python:** they are interpreted rather than compiled, but use byte codes at runtime.
- **The simple act of executing the Perl or Python script automatically triggers the generation of byte codes.**



Dynamic linking

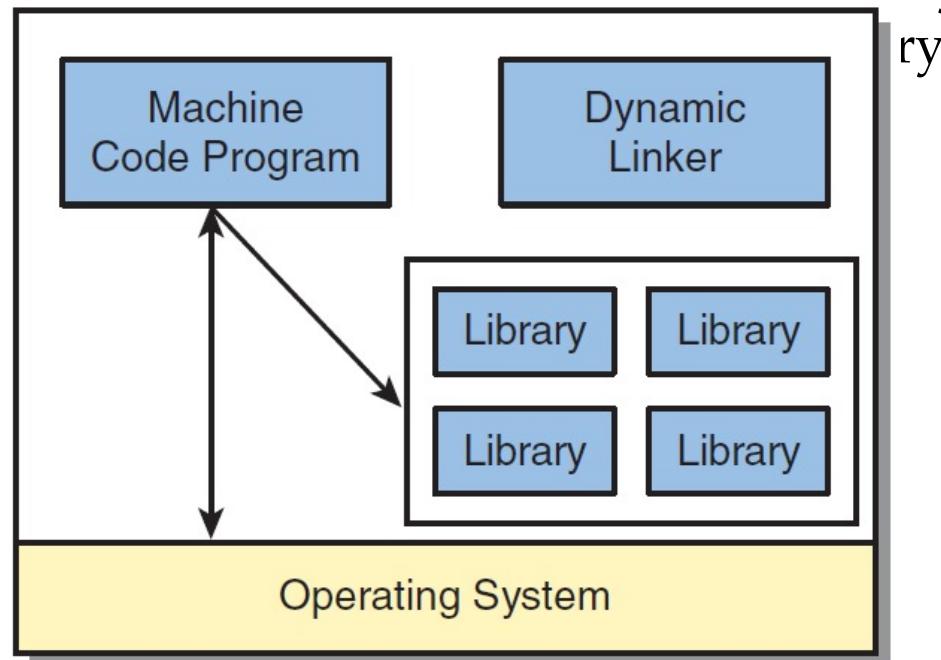
- **Dynamic linking** method doesn't copy the object file into the executable image; instead, it notes which libraries are required to successfully execute the program. 库文件不会在build阶段被加入可执行软件，仅仅做出标记
- When the program starts running, the **libraries are loaded into memory as separate entities** and then are connected with the main program. 程序运行时，根据标记装载库至内存
- A dynamic library is a disk file that is constructed by joining object files. The **library is then collected into the release package and installed on the target machine**. Only then can it be loaded into the machine's memory. 发布软件时，记得将程序所依赖的所有动态库都复制给用户

你的实验，提交到GitHub的时候，切记把各种lib都一并提交上来

Dynamic linking

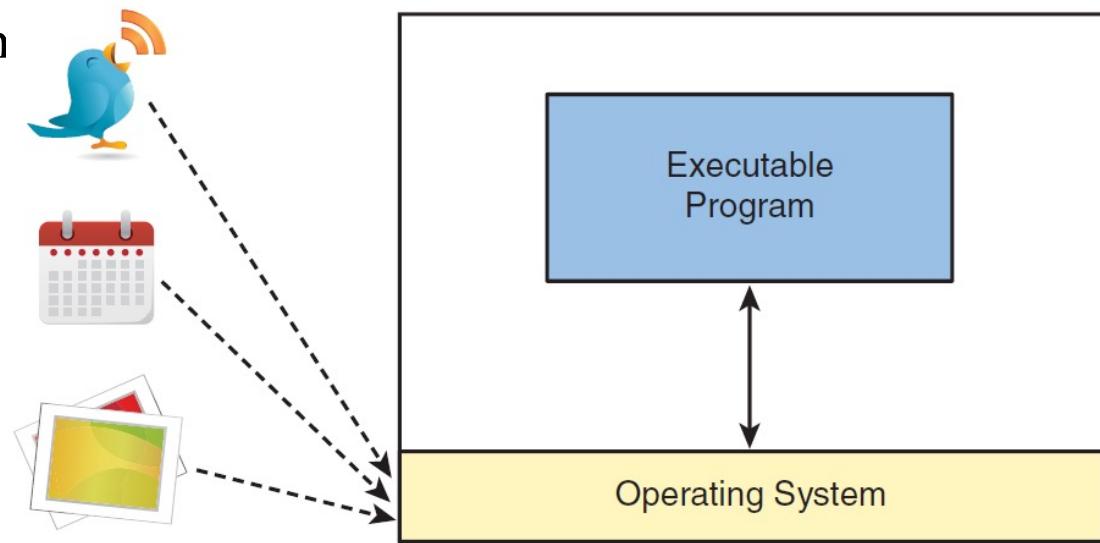
- **Advantages:**

- It's possible to **upgrade** to a newer version of a library (adding features or fixing bugs), without needing to re-create the executable program.
- Many operating systems can optimize their memory usage by loading only **a single copy of the library into memory**, yet **sharing** it with other



Configuration and Data Files

- Any program of significant size uses external data sources, such as a file on a disk.
- Your program makes calls into the operating system to request that data be read into memory.
 - A bitmap graphic image displayed onscreen
 - A sound stored as a digitized wave form
 - A configuration file that customizes the behavior of a program
 - A set of documents containing online help text
 - A database containing names and addresses

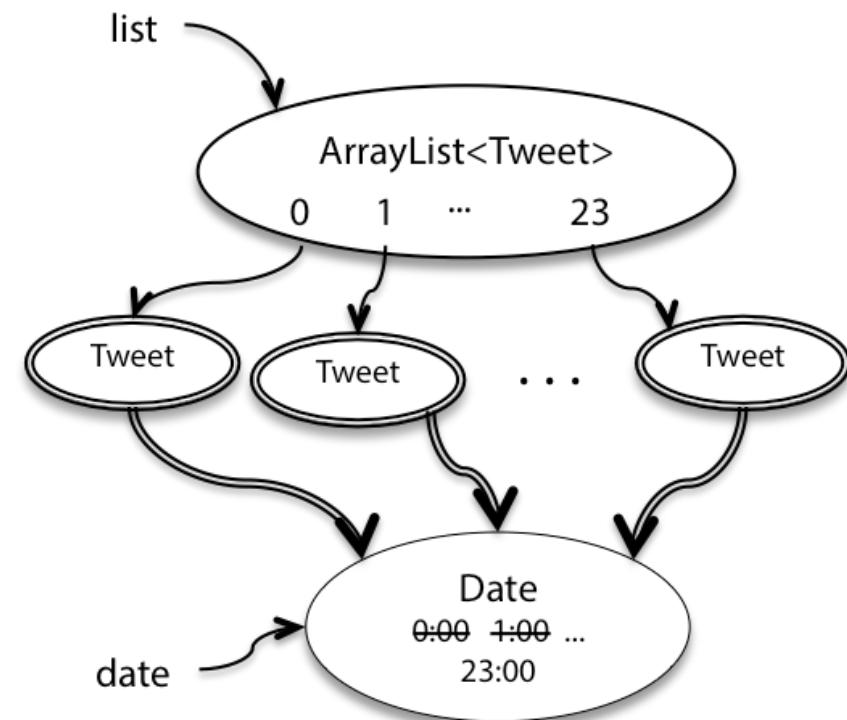
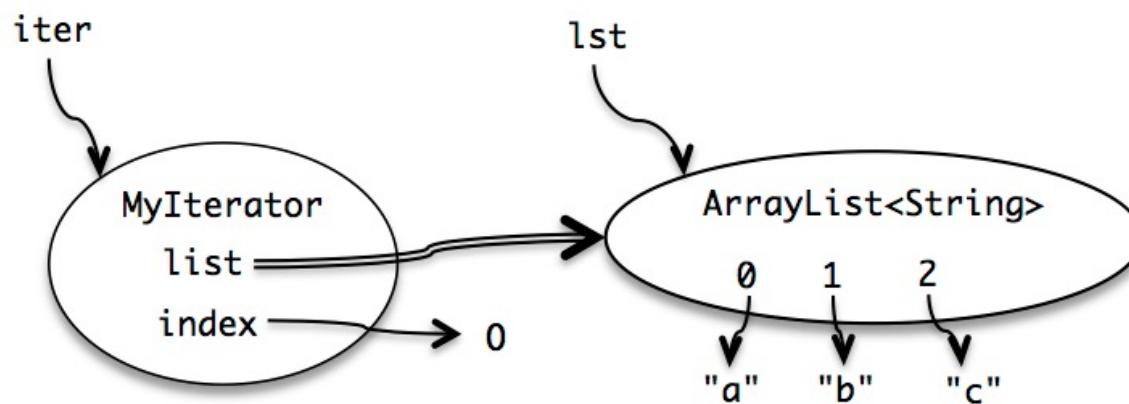


Distributed Programs

- For example, a software system might use the client/server model, with a single server program running on one computer and a large number of client programs running on many other computers.
- In this scenario, the build system could create two release packages, given that different people will be installing the server program versus the client program.
- Alternatively, the same release package could be used to install the two separate programs.
- 分布式程序的运行态：需要多个运行程序，分别部署于多个计算机物理环境。

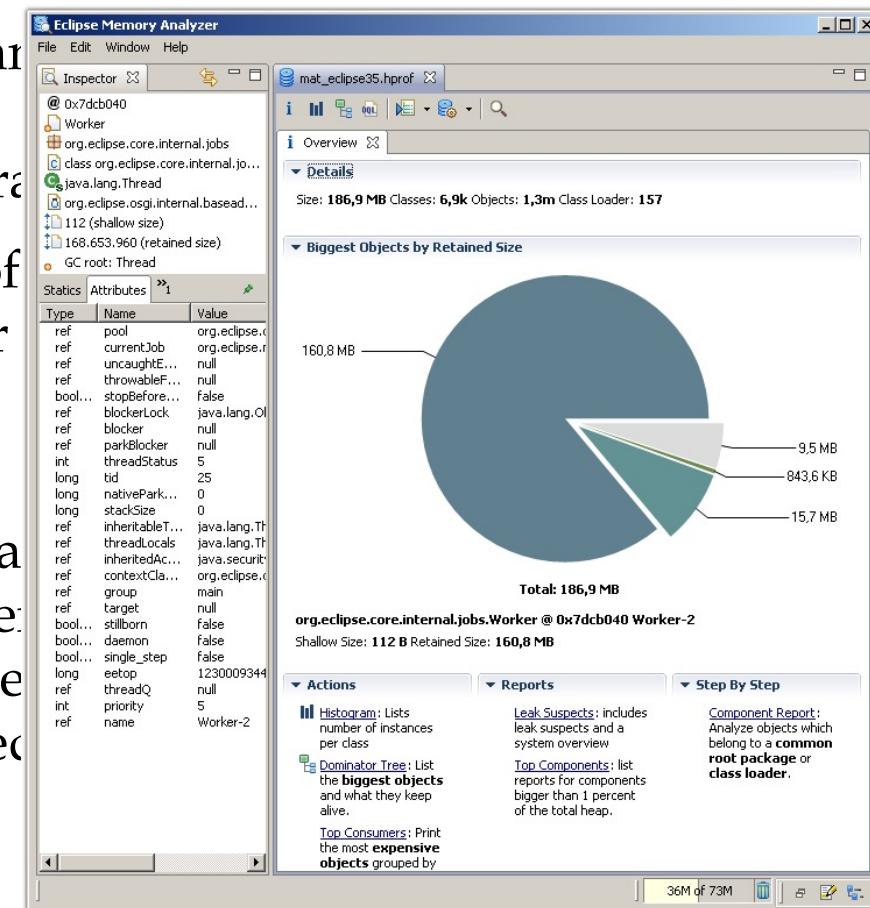
(5) Run-time, moment, and code-level view

- Snapshot diagram: focusing on variable-level execution states in the memory of a target computer.
- Fine-grained states of a program.
- 代码快照图：描述程序运行时内存里变量层面的状态

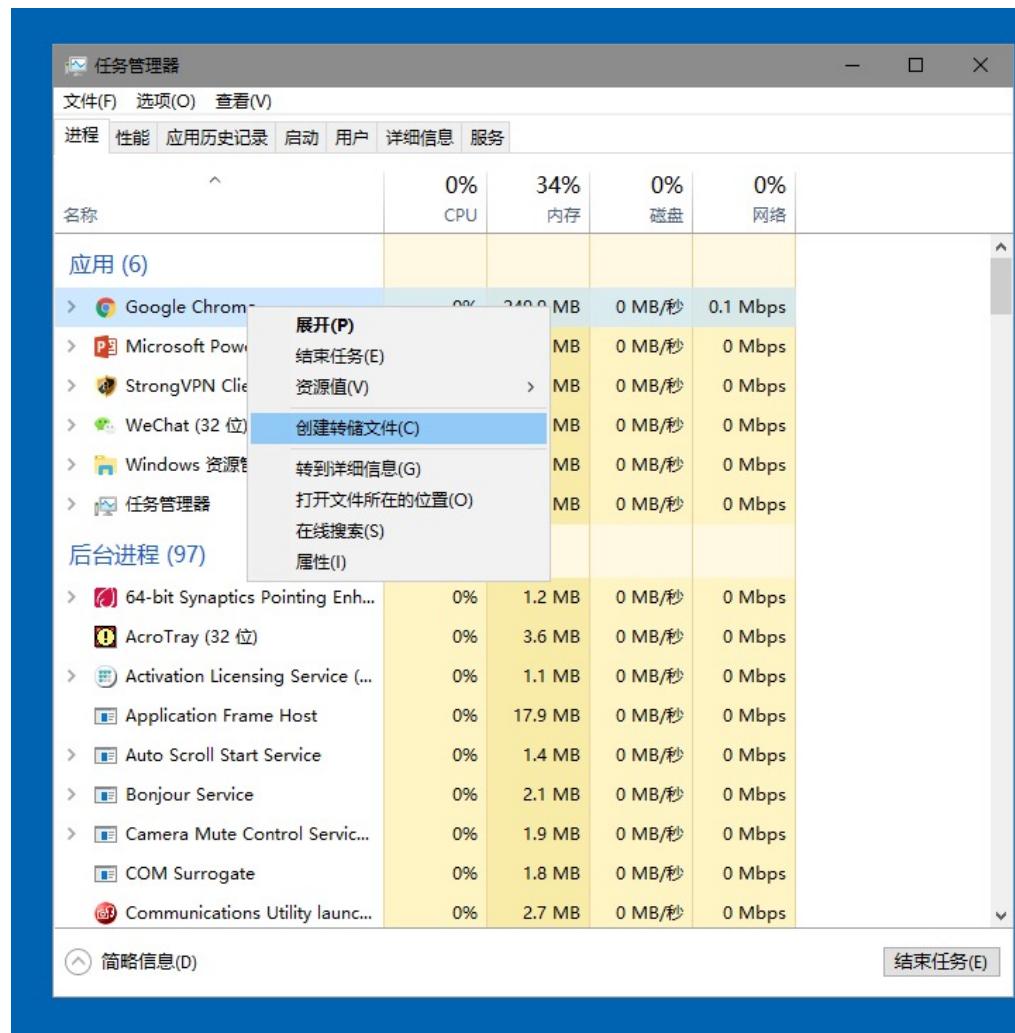


Memory dump (内存信息转储)

- **Memory dump:** a file on hard disk containing a copy of the contents of a process's memory, produced when a process is aborted by certain kinds of internal error or signal.
 - **Debuggers** can load the dump file and display the information it contains about the state of the running program.
 - **Information** includes the contents of registers, the call stack and all other program data (counters, variables, switches, flags, etc).
 - It is taken in order to **analyze** the state of the program, and the programme looks into the memory buffers to see which data items were being worked on at the time of failure.

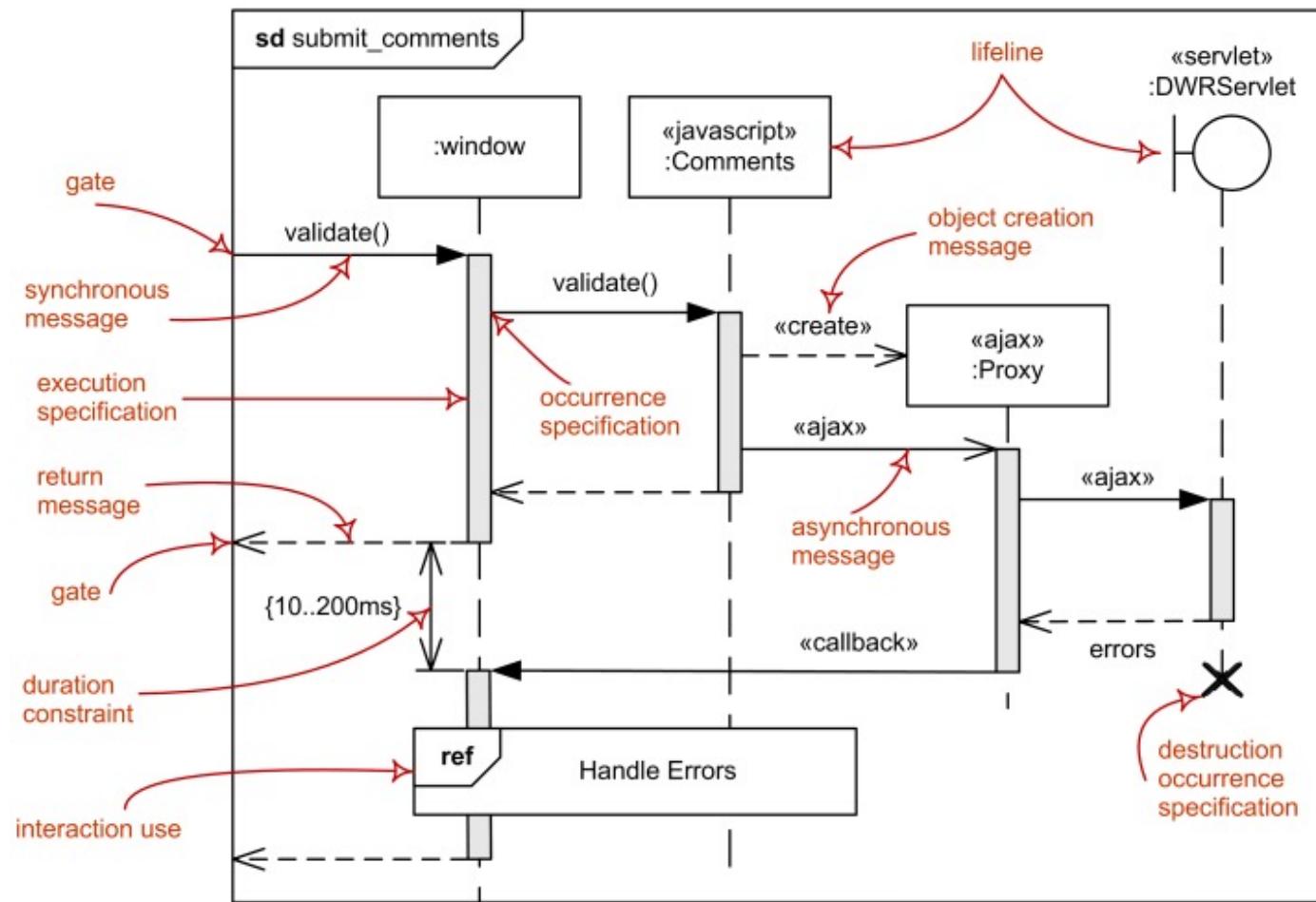


Memory dump



(6) Run-time, period and code-level view

- Sequence diagram in UML: interactions among program units (objects)



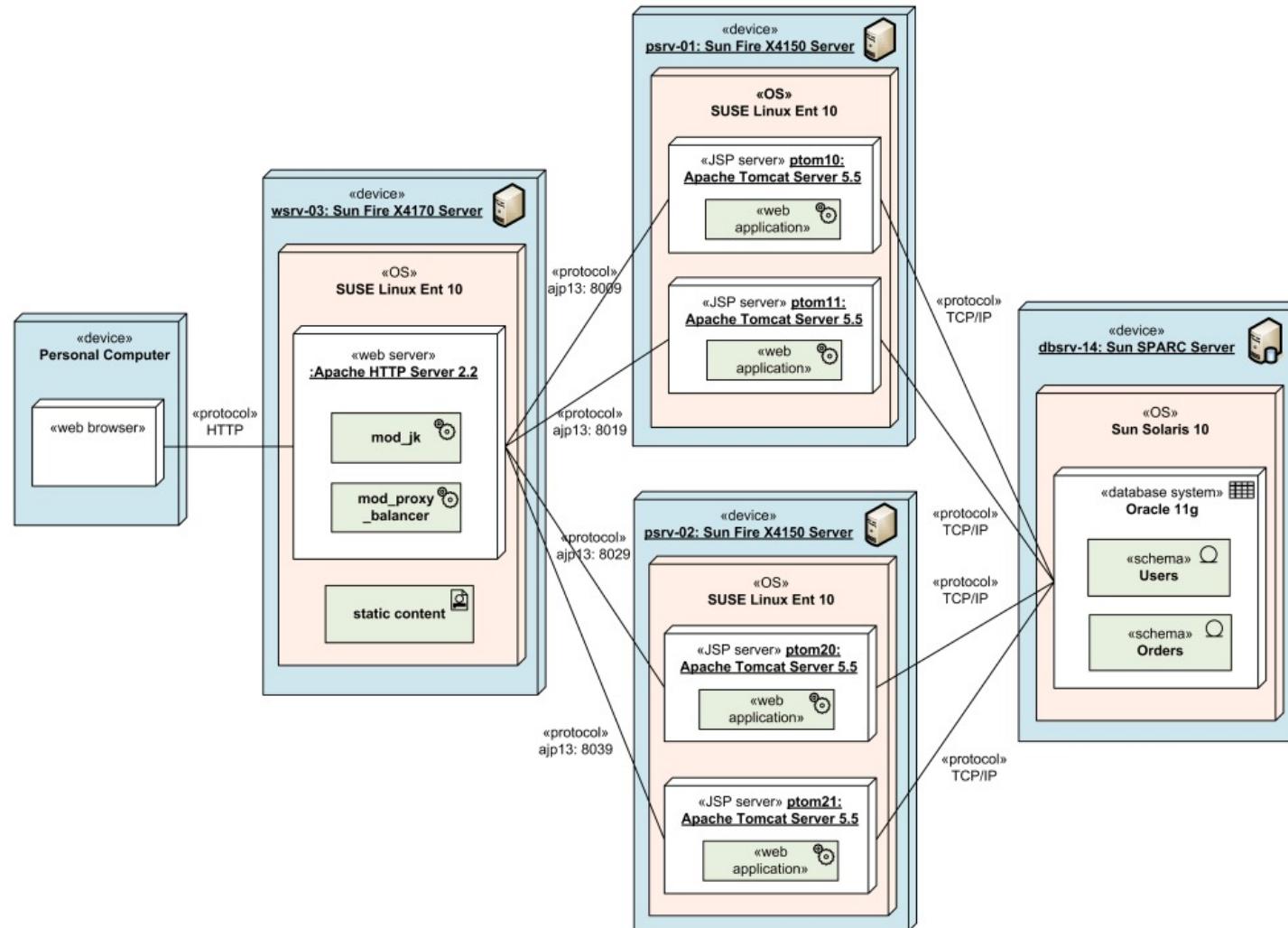
Execution tracing 执行跟踪

- Tracing involves a specialized use of logging to record information about a program's execution. 用日志方式记录程序执行的调用次序
 - This is typically used by programmers for debugging purposes, and depending on the type and detail of information contained in a trace log, by experienced administrators or technical-support personnel and by software monitoring tools to diagnose common problems with software.

```
09-26 10:59:38.056 28584-28584/  
java.lang.NullPointerException  
at android.content.Context.  
at android.widget.Toast.  
at android.widget.Toast.  
at com.app.app.MainActivity.  
at android.os.Handler.ha  
at android.os.Handler.di  
at android.os.Looper.loo  
at android.app.ActivityT  
at java.lang.reflect.Met  
at java.lang.reflect.Met  
at com.android.internal.  
at com.android.internal.  
at dalvik.system.NativeS  
0    java.lang.RuntimeException  
!    1  at com.crittercism.testapp.errors.CustomError.crash(CustomError.java:57)  
     2  at com.crittercism.testapp.fragments.ErrorFragment$4.onClick(ErrorFragment.java:150)  
     3  at android.view.View.performClick(View.java:4438)  
     4  at android.view.View$PerformClick.run(View.java:18422)  
     5  at android.os.Handler.handleCallback(Handler.java:733)  
     6  at android.os.Handler.dispatchMessage(Handler.java:95)  
     7  at android.os.Looper.loop(Looper.java:136)  
     8  at android.app.ActivityThread.main(ActivityThread.java:5001)  
     9  at java.lang.reflect.Method.invokeNative(Native Method)  
    10  at java.lang.reflect.Method.invoke(Method.java:515)  
    11  at com.android.internal.os.ZygoteInit$MethodAndArgsCaller.run(ZygoteInit.java:785)  
    12  at com.android.internal.os.ZygoteInit.main(ZygoteInit.java:601)  
    13  at de.robv.android.xposed.XposedBridge.main(XposedBridge.java:132)  
    14  at dalvik.system.NativeStart.main(Native Method)  
    15  Caused by: java.lang.NullPointerException  
    16  at com.crittercism.testapp.errors.NullPointerCustomError.performError(NullPointerCustomError.java:10)  
    17  at com.crittercism.testapp.errors.CustomError.initiateError(CustomError.java:83)
```

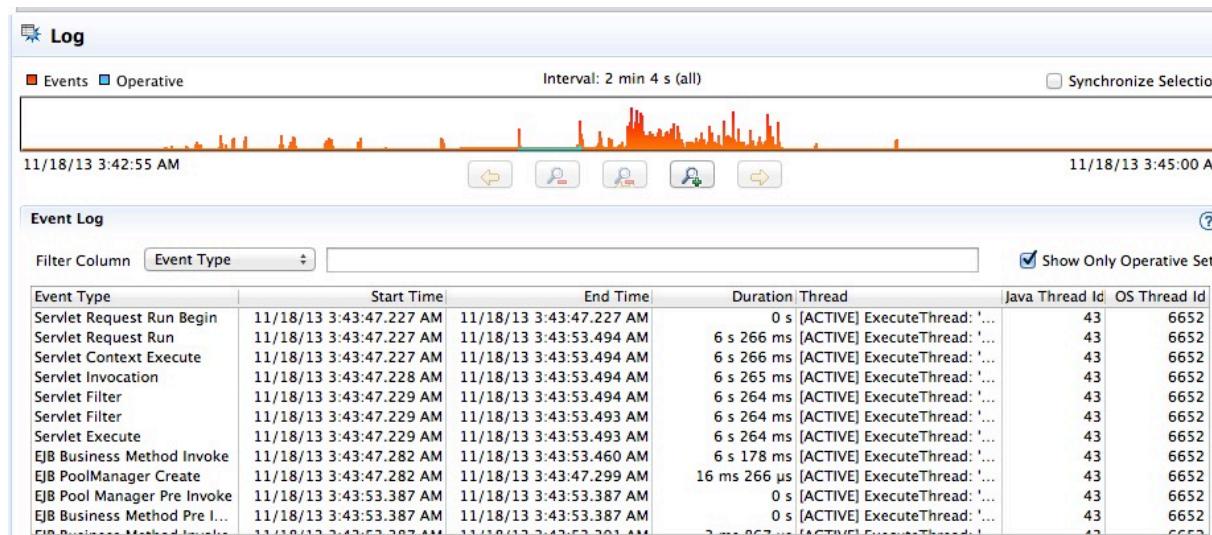
(7) Run-time, moment, and component-level view

- Deployment diagram in UML



(8) Run-time, period, and component-level view

- Event logging provides system administrators with information useful for diagnostics and auditing. 事件日志：系统层面
 - The different classes of events that will be logged, as well as what details will appear in the event messages, are considered in development cycle.
- Each class of event to be assigned a unique “code” to format and output a human-readable message.
 - This facilitates localization and allows system administrators to more easily obtain information on problems that occur.



Execution tracing and event logging

Event logging (构件/系统层面)	Execution tracing (代码层面)
Consumed primarily by system administrators	Consumed primarily by developers
Logs "high level" information (e.g. failed installation of a program)	Logs "low level" information (e.g. a thrown exception)
Must not be too "noisy" (contain many duplicate events or information not helpful to its intended audience)	Can be noisy
A standards-based output format is often desirable, sometimes even required	Few limitations on output format
Event log messages are often localized	Localization is rarely a concern
Addition of new types of events, as well as new event messages, need not be agile	Addition of new tracing messages <i>must</i> be agile

What we are focused on in this semester

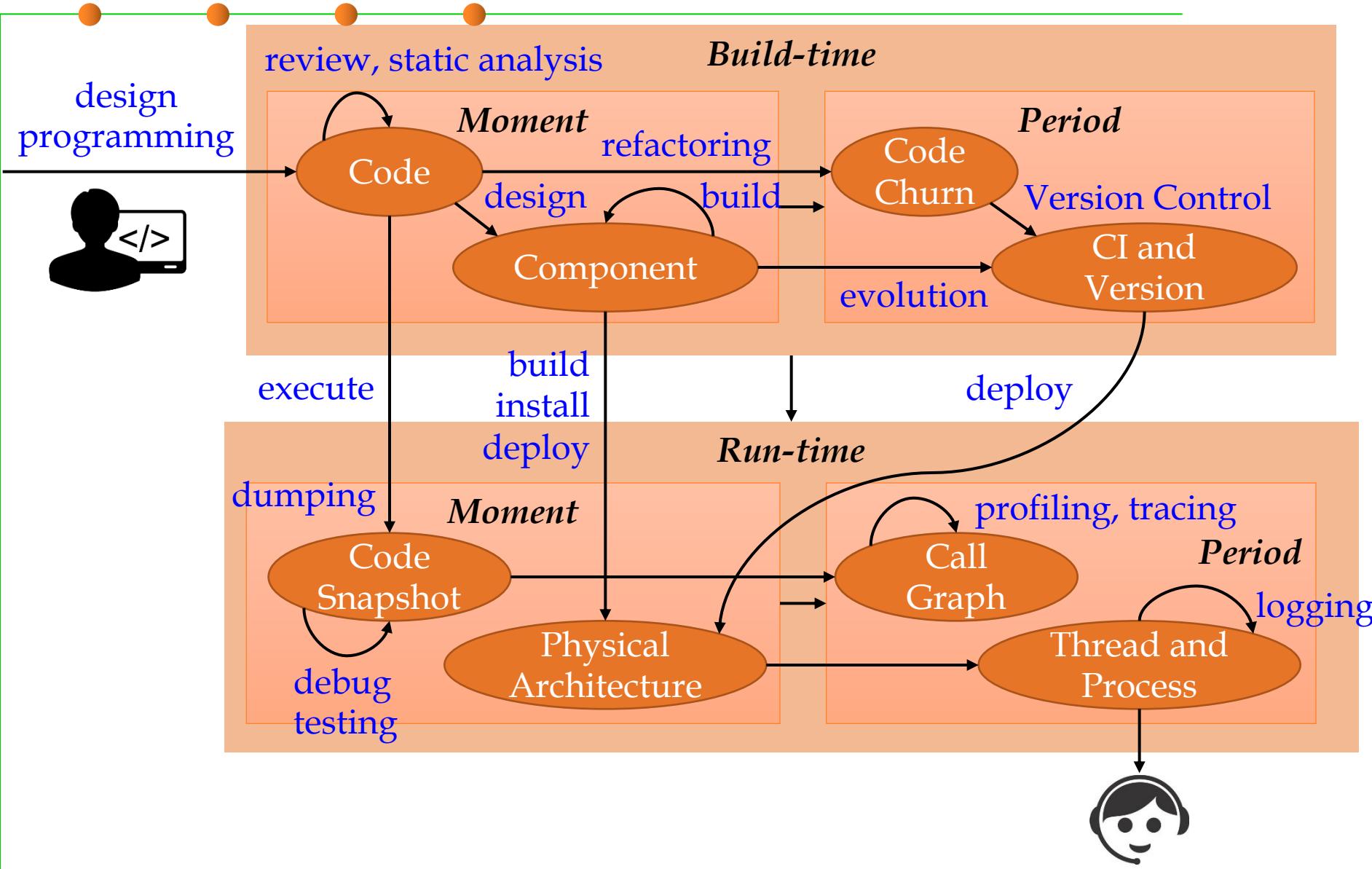
	Moment	Period	
	Code-level	Component-level	Code-level
Build-time	Source code, AST, Interface-Class-Attribute	Package, File, Static Linking, Library, Test Case,	Code Churn
	Method (Class Diagram)	Build Script (Component Diagram)	Configuration Item, Version
Run-time	Code Snapshot, Memory dump	Package, Library, Dynamic linking, Configuration, Database, Middleware, Network,	Execution stack trace, Concurrent multi-threads
			Event log, Multi-processes, Distributed processes



2 Software construction: Transformation between views



Software construction: transformation btw views



Types of Transformations in Software Construction

- 
- **$\emptyset \Rightarrow \text{Code}$**
 - Programming / Coding (ADT/OOP)
 - Review, static analysis/checking
 - **$\text{Code} \Rightarrow \text{Component}$**
 - Design (ADT/OOP; Reusability; Maintainability)
 - Build: compile, static link, package, install, etc
 - **$\text{Build-time} \Rightarrow \text{Run-time}$**
 - Install / deploy
 - Debug, unit/integration testing (Robustness and Correctness)
 - **$\text{Moment} \Rightarrow \text{Period}$**
 - Version control
 - Loading, dynamic linking, execution (dumping, profiling, logging)
 - Concurrent threads



3 Quality properties of software systems



External and internal quality factors

- **External quality factors:** qualities such as speed or ease of use, whose presence or absence in a software product may be detected by its users.

External quality factors affect users
外部质量因素 影响 用户

- Other qualities applicable to a software product, such as being modular, or readable, are **internal factors**, perceptible only to developers who have access to the actual software text.

Internal quality factors affect the software itself and its developers
内部质量因素 影响 软件本身和它的开发者

- In the end, only external factors matter.
- But the key to achieving these external factors is in the internal ones: for the users to enjoy the visible qualities, the designers and implementers must have applied internal techniques that will ensure the hidden qualities.

External quality results from internal quality
外部质量取决于内部质量

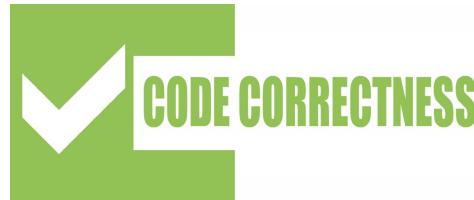


(1) External quality factors



External 1: Correctness

- **Correctness** is the ability of software products to perform their exact tasks, as defined by their specification. 按照预先定义的“规约”执行
- **Correctness is the prime quality** 正确性：最重要的质量指标



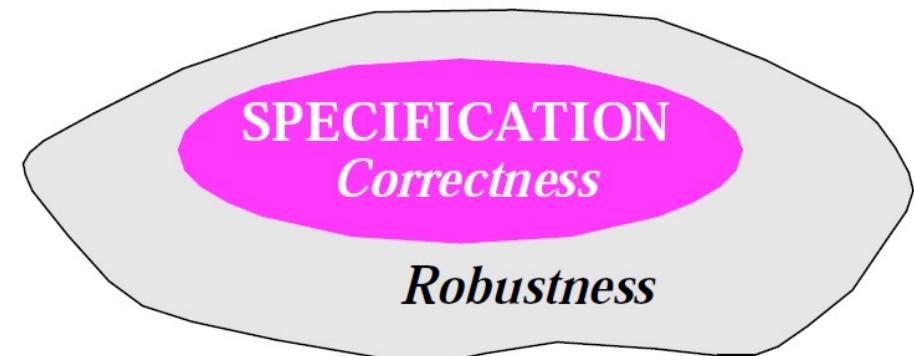
Assume a software system is developed in layers.
Each layer guarantees its correctness under the
assumption that its lower layer is also correct.
每一层保证自己的正确性，同时假设其下层是正确的

External 1: Correctness

- Approaches of ensuring correctness: Testing and debugging
测试和调试: 发现不正确、消除不正确 \Rightarrow Robustness (Chapter 6)
- Defensive programming such as typing and assertions
防御式编程: 在写程序的时候就确保正确性 meant to help build software that is correct from the start – rather than debugging it into correctness. \Rightarrow Robustness (Chapter 6)
- Formal approach: “check”, “guarantee” and “ensure”
形式化方法: 通过形式化验证发现问题
 - Mathematical techniques for formal program specification and verification
 - \Rightarrow Formal Language, Graduate courses

External 2: Robustness

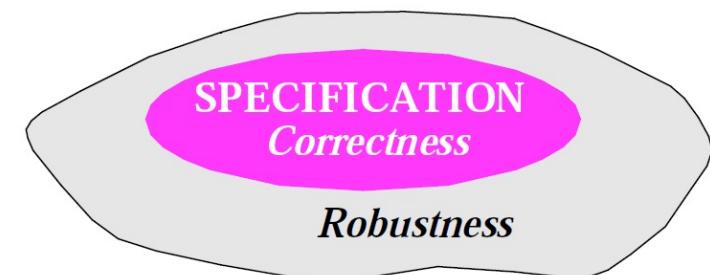
- Robustness is the ability of software systems to react appropriately to abnormal conditions 健壮性：针对异常情况的处理
 - Robustness complements correctness. 健壮性是对正确性的补充
 - Correctness addresses the behavior of a system in cases covered by its specification; 正确性：软件的行为要严格地符合规约中定义的行为
 - Robustness characterizes what happens outside of that specification. 健壮性：出现规约定义之外的情形的时候，软件要做出恰当的反应
- Robustness is to make sure that if such cases do arise, the system does not cause catastrophic events; it should produce appropriate error messages, terminate its execution cleanly, or enter a so-called “graceful degradation” mode.
- 健壮性：出现异常时不要“崩溃”



External 2: Robustness

- Robustness is concerned with “**abnormal case**”, which implies that the notions of normal and abnormal case are always relative to a certain specification “**normal**” 和 “**abnormal**” 是主观而非客观
 - An abnormal case is simply a case that is not covered by the specification 未被specification覆盖的情况即为“**异常情况**”
 - If you widen the specification, cases that used to be abnormal become normal – even if they correspond to events such as erroneous user input that you would prefer not to happen 所谓的“**异常**”，取决于spec的范畴
 - “Normal” in this sense does not mean “desirable”, but simply “planned for in the design of the software”.
 - Although it may seem paradoxical at first that erroneous input should be called a normal case, any other approach would have to rely on subjective criteria, and so would be useless.

⇒Exception handling (Chapter 6)



External 3: Extendibility

- Extendibility (可扩展性) is the ease of adapting software products to changes of specification. 对软件的规约进行修改，是否足够容易？
- The problem of extendibility is one of scale 规模越大，扩展起来越不容易
 - For small programs change is usually not a difficult issue; but as software grows bigger, it becomes harder and harder to adapt.
 - A large software system often looks to its maintainers as a giant house of cards in which pulling out any one element might cause the whole edifice to collapse.
- We need extendibility because at the basis of all software lies some human phenomenon and hence fickleness 为什么要扩展：应对变化
 - Traditional approaches did not take enough account of change, relying instead on an ideal view of the software lifecycle where an initial analysis stage freezes the requirements, the rest of the process being devoted to designing and building a solution.

External 3: Extendibility

- Two principles are essential for improving extendibility:
 - *Design simplicity*: a simple architecture will always be easier to adapt to changes than a complex one. 简约主义设计
 - *Decentralization*: the more autonomous the modules, the higher the likelihood that a simple change will affect just one module, or a small number of modules, rather than triggering off a chain reaction of changes over the whole system. 分离主义设计

⇒ Chapter 3 (ADT and OOP)
⇒ Chapter 4/5 (Modularity and adaptability)

***Great Design
is great complexity
presented via simplicity***

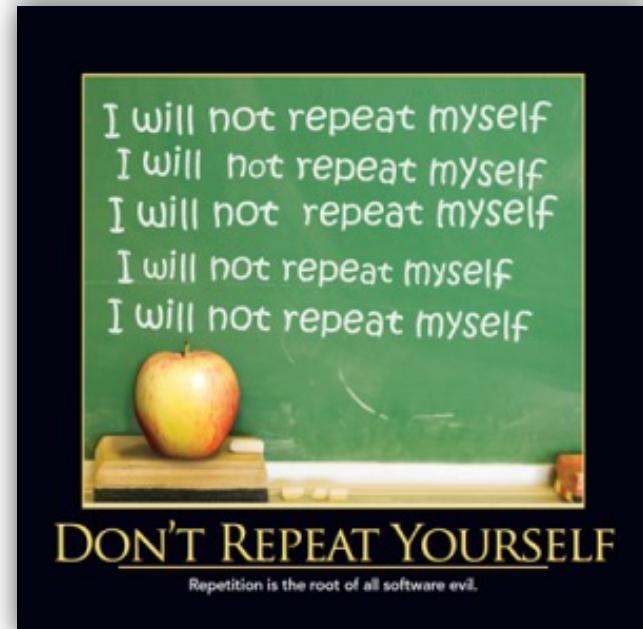
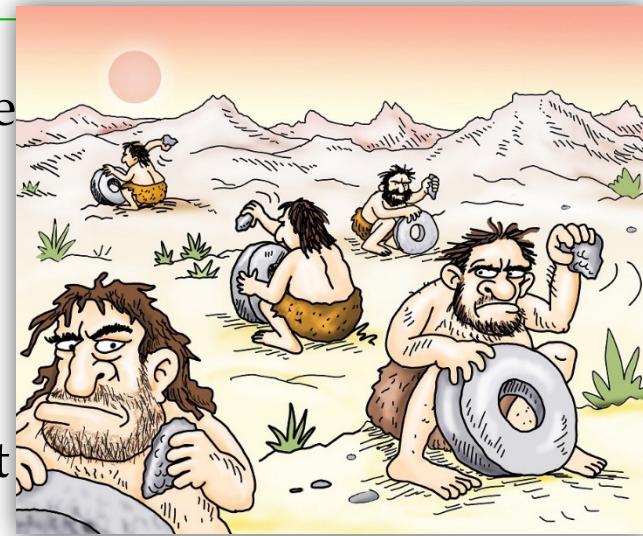
- M. Cobanli



External 4: Reusability

- **Reusability (可复用性)** is the ability of software elements to serve for the construction of many different applications. 一次开发，多次使用
- The need for reusability comes from the observation that software **systems often follow similar patterns**; it should be possible to exploit this **commonality** and avoid reinventing solutions to problems that have been encountered before. **发现共性**
 - A reusable software element will be applicable to many different developments.
 - ***Don't Repeat Yourself (DRY)***
 - ***Don't Re-invent the Wheel***

⇒ **Chapter 4 (Design for/with reuse)**



External 5: Compatibility

- **Compatibility (兼容性)** is the ease of combining software elements with others. **不同的软件系统之间相互可容易的集成**
- **Compatibility is important because we do not develop software elements in a vacuum (真空): they need to interact with each other.**
- **But they too often have trouble interacting because they make conflicting assumptions about the rest of the world.**
 - An example is the wide variety of incompatible file formats supported by many operating systems. A program can directly use another's result as input only if the file formats are compatible. **(文件格式的兼容性)**

External 5: Compatibility

- The key to compatibility lies **in homogeneity of design** (保持设计的同构性), and in agreeing on standardized conventions for inter-program communication.
- **Approaches include:**
 - **Standardized file formats**, as in the Unix system, where every text file is simply a sequence of characters.
 - **Standardized data structures**, as in Lisp systems, where all data, and programs as well, are represented by binary trees (called lists in Lisp).
 - **Standardized user interfaces**, as on various versions of Windows, OS/2 and MacOS, where all tools rely on a single paradigm for communication with the user, based on standard components such as windows, icons, etc.
- More general solutions are obtained by defining **standardized access protocols** to all important entities manipulated by the software.



External 6: Efficiency

- **Efficiency** is the ability of a software system to place as few demands as possible on hardware resources, such as processor **time**, space occupied in internal and external **memories**, **bandwidth** used in communication devices.
- **Efficiency does not matter much if the software is not correct** (*"do not worry how fast it is unless it is also right"*). 性能毫无意义，除非有足够的正确性
 - The concern for efficiency must be balanced with other goals such as extendibility and reusability; 对性能的关注 要与 其他质量属性进行折中
 - Extreme optimizations make the software so specialized as to be unfit for change and reuse. 过度的优化导致软件不再适应变化和复用
- Algorithms, I/O, memory management, etc.

Abstract concepts for correctness of computation vs. Concrete implementation for performance through optimization

External 6: Efficiency

过早优化是万恶之源



We should forget
about small
efficiencies, say about
97% of the time:
premature
optimization is the
root of all evil.

Donald Knuth

External 7: Portability (可移植性)

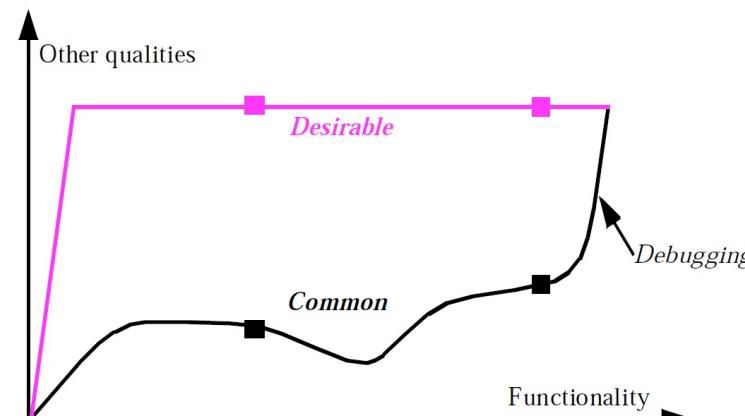
- **Portability** is the ease of transferring software products to various hardware and software environments. 软件可方便的在不同的技术环境之间移植
- Portability addresses variations not just of the physical hardware but more generally of the **hardware-software machine**, the one that we really program, which includes the operating system, the window system if applicable, and other fundamental tools. 硬件、操作系统

External 8: Ease of use

- Ease of use (易用性) is the ease with which people of various backgrounds and qualifications can learn to use software products and apply them to solve problems. (容易学、安装、操作、监控)
 - It also covers the ease of installation, operation and monitoring.
- How to provide detailed guidance and explanations to novice users, without bothering expert users who just want to get right down to business. (给用户提供详细的指南)
- Structural simplicity
 - A well-designed system, built according to a clear, well thought-out structure, will tend to be easier to learn and use than a messy one.
- Know the user
 - The argument is that a good designer must make an effort to understand the system's intended user community.

External 9: Functionality

- Functionality is the extent of possibilities provided by a system.
- *Featurism (often “creeping featurism”)* 程序设计中一种不适宜的趋势，即软件开发者增加越来越多的功能，企图跟上竞争，其结果是程序极为复杂、不灵活、占用过多的磁盘空间
 - The easier problem is the **loss of consistency** that may result from the addition of new features, affecting its ease of use. Users are indeed known to complain that all the “bells and whistles” of a product’s new version make it horrendously complex.
 - The more difficult problem is to avoid being so focused on features as to forget the other qualities (**Ignorance of overall quality**).



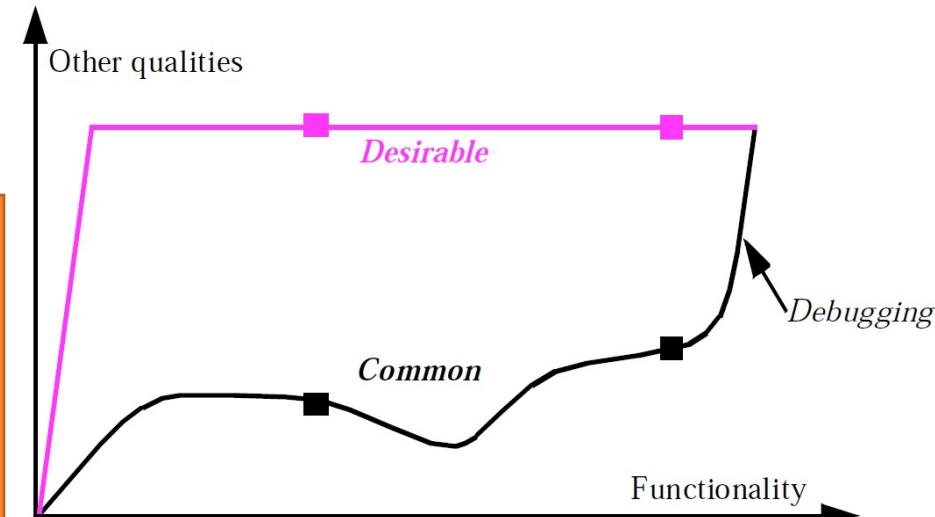
Osmond's curves

External 9: Functionality

- What Osmond suggests (the color curve) is, aided by the quality-enhancing techniques of OO development, to maintain the quality level constant throughout the project for all aspects but functionality.
- You just do not compromise on reliability, extendibility and the like: you refuse to proceed with new features until you are happy with the features you have.

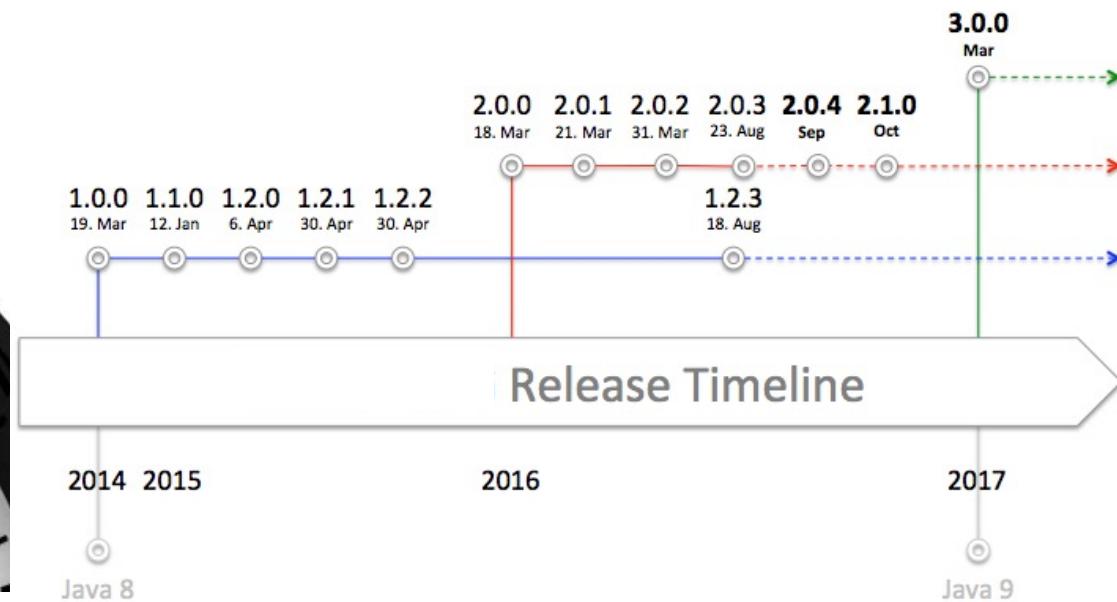
⇒ Chapter 2 (Agile, SCM)

Start with a small set of key features with all quality factors considered.
Add more features gradually during development process and guarantee the same quality as key features.
每增加一小点功能，都确保其他质量属性不受到损失



External 10: Timeliness

- **Timeliness (及时性)** is the ability of a software system to be released when or before its users want it.
- A great software product that appears too late might miss its target altogether.



External 10++: Other qualities

- **Verifiability** (可验证性) is the ease of preparing acceptance procedures, especially test data, and procedures for detecting failures and tracing them to errors during the validation and operation phases.
- **Integrity** (完整性) is the ability of software systems to protect their various components (programs, data) against unauthorized access and modification.
- **Repairability** (可修复性) is the ability to facilitate the repair of defects.
- **Economy** (经济性), the companion of timeliness, is the ability of a system to be completed on or below its assigned budget.

If you can't
MEASURE it
you can't **MANAGE** it.





(2) Internal quality factors

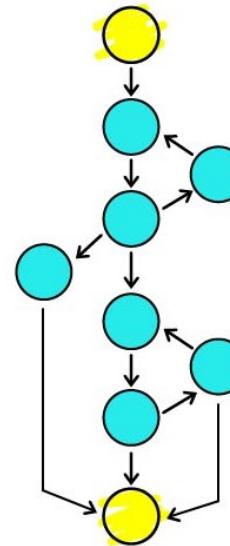
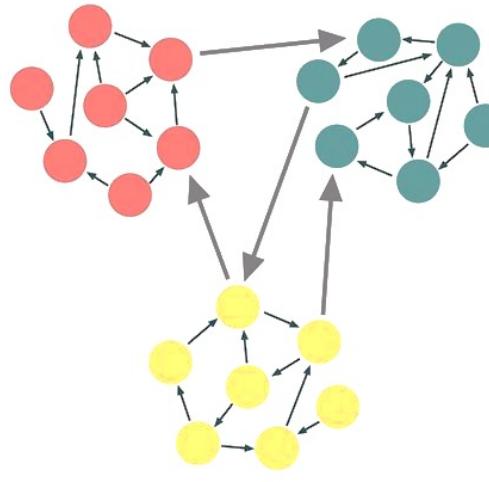


Internal quality factors

Complexity is the enemy of almost any external quality factors!

- Source code related factors such as **Lines of Code (LOC)**, **Cyclomatic Complexity**, etc
- Architecture-related factors such as **coupling**, **cohesion**, etc

- **Readability**
- **Understandability**
- **Clearness**
- **Size**



Internal quality factors are usually used as partial measurement of external quality factors.

system	Lines of code (LOC)
Netscape	17,000,000
Space shuttle	10,000,000
Linux	1,500,000
Windows XP	40,000,000
Boeing 777	7,000,000



(3) Tradeoff between quality properties



Tradeoff between quality properties 折中

- How can one get *integrity* without introducing protections of various kinds, which will inevitably hamper *ease of use*?
- *Economy* often seems to fight with *functionality*.
- Optimal *efficiency* would require perfect adaptation to a particular hardware and software environment, which is the opposite of *portability*, and perfect adaptation to a specification, where *reusability* pushes towards solving problems more general than the one initially given.
- *Timeliness* pressures might tempt us to use “Rapid Application Development” techniques whose results may not enjoy much *extendibility*.

Integrity vs. ease of use
Economy vs. functionality
Efficiency vs. portability
Efficiency vs. reusability
Economy vs. reusability
Timeliness vs. extendibility

Tradeoff between quality properties

- Developers need to make **tradeoffs**.
 - Too often, developers make these tradeoffs implicitly, without taking the time to examine the issues involved and the various choices available; efficiency tends to be the dominating factor in such silent decisions.
 - A true software engineering approach implies an effort to state the criteria clearly and make the choices consciously.
 - 正确的软件开发过程中，开发者应该将不同质量因素之间如何做出折中的设计决策和标准明确的写下来
- Necessary as tradeoffs between quality factors may be, one factor stands out from the rest: **correctness**.
 - There is never any justification for compromising correctness for the sake of other concerns such as efficiency.
 - If the software does not perform its function, the rest is useless.
 - 虽然需要折中，但“正确性”绝不能与其他质量因素折中。

Key concerns of software construction

- All the qualities discussed above are important.
- 最重要的几个质量因素
But in the current state of the software industry, four stand out:
 - *Correctness* and *robustness*: reliability
 - Systematic approaches to software construction
 - Formal specification
 - Automatic checking during development process
 - Better language mechanism
 - Consistency checking tools
 - *Extendibility* and *reusability*: modularity

How OOP improves quality

- **Correctness:** encapsulation, decentralization
- **Robustness:** encapsulation, error handling
- **Extendibility:** encapsulation, information hiding
- **Reusability:** modularity, component, models, patterns
- **Compatibility:** standardized module and interface
- **Portability:** information hiding, abstraction
- **Ease of use:** GUI components, framework
- **Efficiency:** reusable components
- **Timeliness:** modeling, reuse
- **Economy:** reuse
- **Functionality:** extendibility

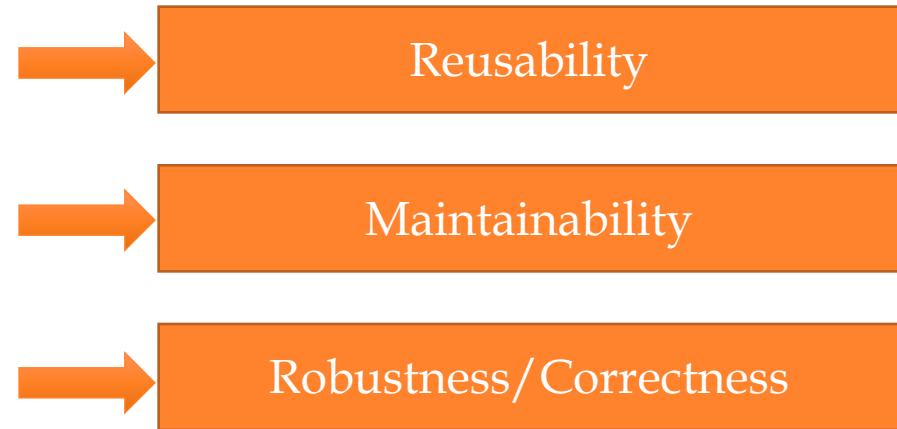


4 Five key quality objectives of software construction



Quality considerations of this course

- Elegant and beautiful code \Rightarrow **easy to understand**, understandability
- Design for/with reuse \Rightarrow **cheap for develop**
- Low complexity \Rightarrow **ready for changes**, easy to extend
- Robustness and correctness \Rightarrow **safe from bug**, not error-prone
- Performance and efficiency \Rightarrow **efficient to run**



Chapter 2 ADT and OOP

Understandability



	Moment		Period	
	Code-level	Component-level	Code-level	Component-level
Build-time	代码的可理解性 (变量/子程序/ 语句的命名与构 造标准、代码布 局与风格、注释、 复杂度) Code Review; Walkthrough; Static Code Analysis; ADT/函数规约	构件/项目的可理解 性 (包的组织、文 件的组织、命名空 间)	Refactoring	Version control
Run-time			Log Trace	

Reusability



	Moment		Period	
	Code-level	Component-level	Code-level	Component-level
Build-time	ADT/OOP; 接口与实现分离; 继承/重载/重写; 组合/代理; 多态; 子类型与泛型; OO设计模式	API design; Library; Framework (for/with reuse); Static linking		
Run-time		Dynamic linking		

Maintainability and Adaptability

	Moment		Period	
	Code-level	Component-level	Code-level	Component-level
Build-time	模块化设计; 聚合度/耦合度; SOLID; OO设计模式; State-based programming; Grammar-based programming	SOLID; GRASP		SCM Version Control
Run-time				

Robustness

	Moment		Period	
	Code-level	Component-level	Code-level	Component-level
Build-time	Error handling; Exception handling; Assertion; Defensive programming; Test-first programming			Continuous Integration; Regression Testing
Run-time		Unit/Integration Testing; Debug; Memory Dumping		Logging Tracing

Performance

Performance

	Moment		Period	
	Code-level	Component-level	Code-level	Component-level
Build-time	代码调优; Design pattern			
Run-time	空间复杂性（内存管理性能）； 时间复杂性（I/O性能）； Memory dump; Garbage Collection (GC)	分布式系统	Performance profiling, analysis and tuning	并行/多线程



Summary

Summary of this lecture

- 
- **Three dimensions of describing a software system:**
 - By phases: build- and run-time views
 - By dynamics: moment and period views
 - By levels: code and component views
 - **Elements, relations, and models of each view**
 - **Software construction: transformation between views**
 - $\emptyset \Rightarrow \text{Code}$
 - $\text{Code} \Rightarrow \text{Component}$
 - $\text{Build-time} \Rightarrow \text{Run-time}$
 - $\text{Moment} \Rightarrow \text{Period}$

Summary

- 
- **Quality properties of software systems**
 - External vs. internal quality factors
 - Important external quality factors
 - Tradeoff between quality factors
 - **Five key quality objectives of software construction**
 - **Easy to understand:** elegant and beautiful code / understandability
 - **Ready for change:** maintainability and adaptability
 - **Cheap for develop:** design for/with reuse: reusability
 - **Safe from bugs:** robustness
 - **Efficient to run:** performance
 - **Construction techniques to be studied in this course (classified by the orientation of five key quality objectives)**



The end

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