



Universidad de Oviedo



Software taxonomies

Patterns, styles, tactics,...



SOFTWARE
ARCHITECTURE

2024-25

Software taxonomies

Building & Maintenance

Configuration management

Modularity

Decomposition at building time

Runtime

Components and connectors

Integration

Allocation

Packaging, distribution, deployment

Business and enterprise environment

Software construction & maintenance

Software construction & maintenance

Configuration management



Software: product or service

Software as a Product (SaaP):

Software deliverable

Commercial model: software is sold to clients

Software distributed or downloaded

Example: Microsoft Office

Software as a Service (SaaS):

Software deployed

Commercial model: clients subscribe to it

Software usually available at some URL

Example: Google docs

Software configuration management

Managing the evolution of software

Manages all aspects of software construction

Especially, how software evolves and changes

Aspects:

Identifying baselines and configuration items

Baseline: A work product subject to management

It contains configuration items: documents, code files, etc...

Configuration control & auditing

Version control systems

Building management and automation

Teamwork

Defect and issues tracking

Software construction

Overview of methodologies

Traditional, iterative, agile

Construction tools

Languages, tools, etc.

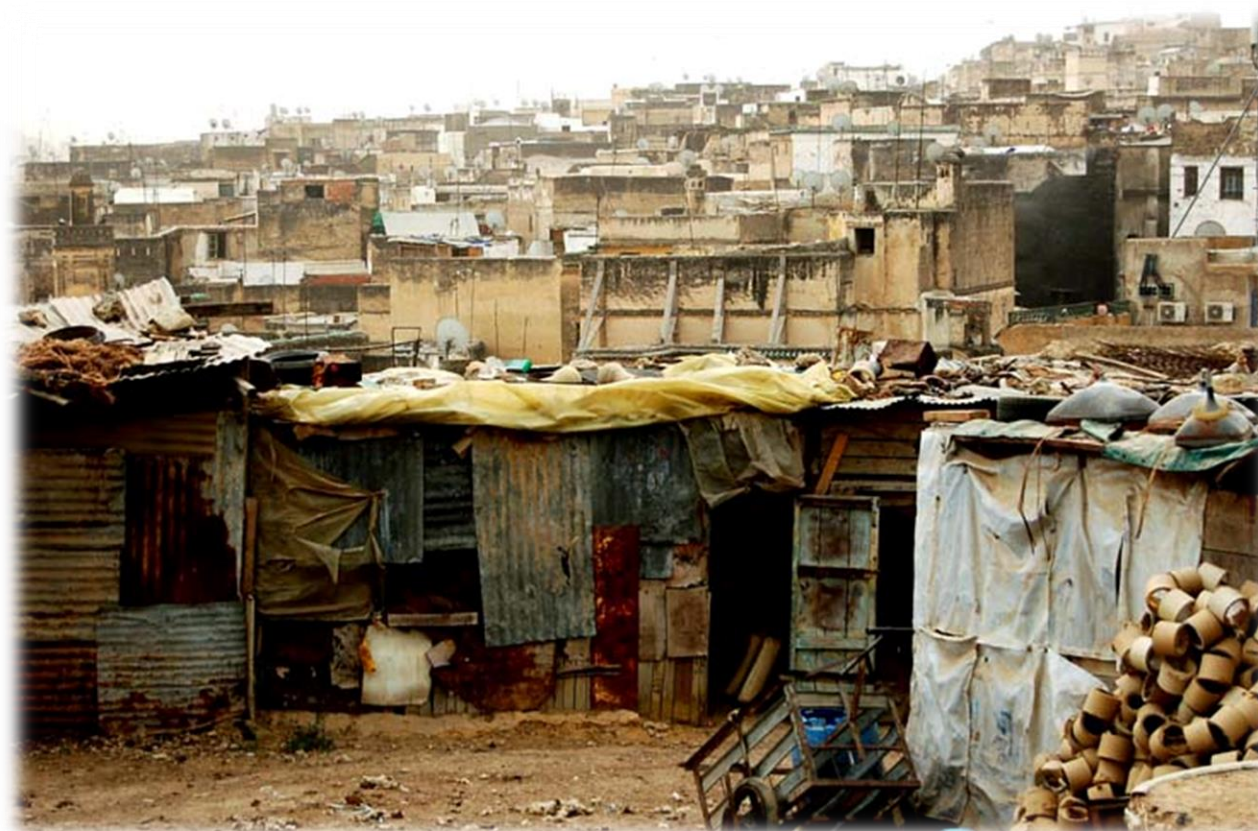
Incremental piecemeal

Development by need

Codification without following the architecture

Throw-away software

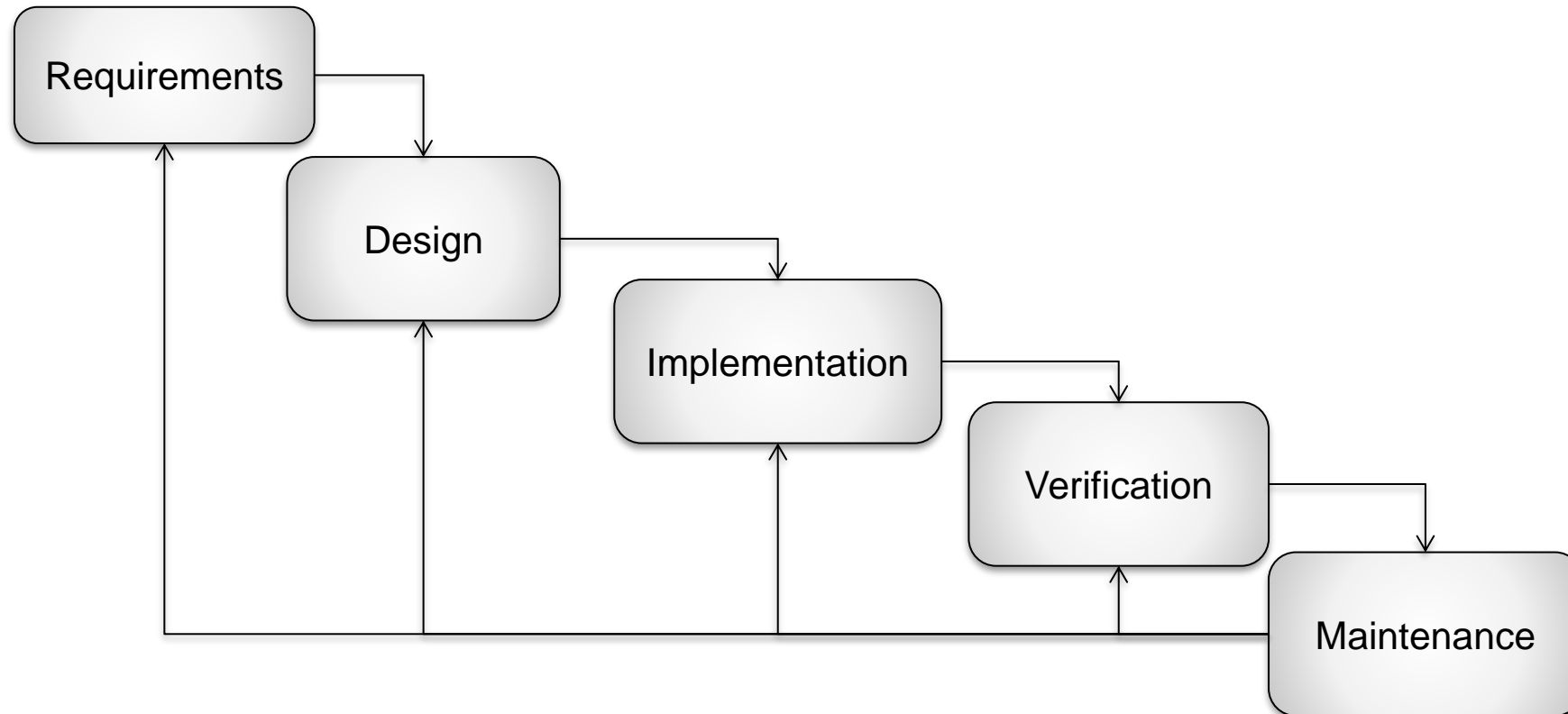
Budget constraints



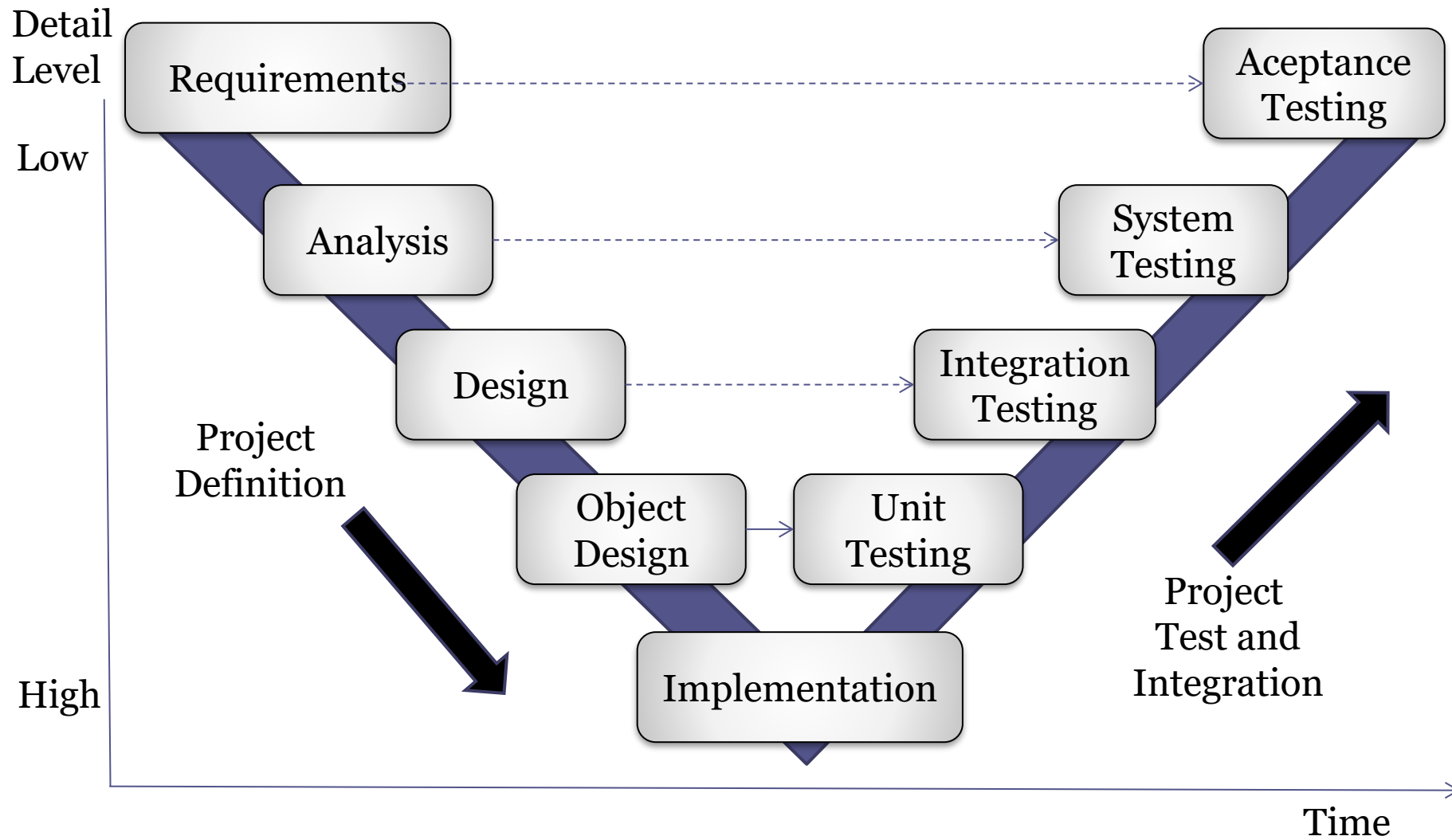
Waterfall

Software Development Life Cycle (SDLC)

Waterfall model identified as antipattern in 1970s



V Model



Big Design Up Front

Anti-pattern of traditional models

Too much documentation that nobody reads

Documentation different from developed system

Architecture degradation

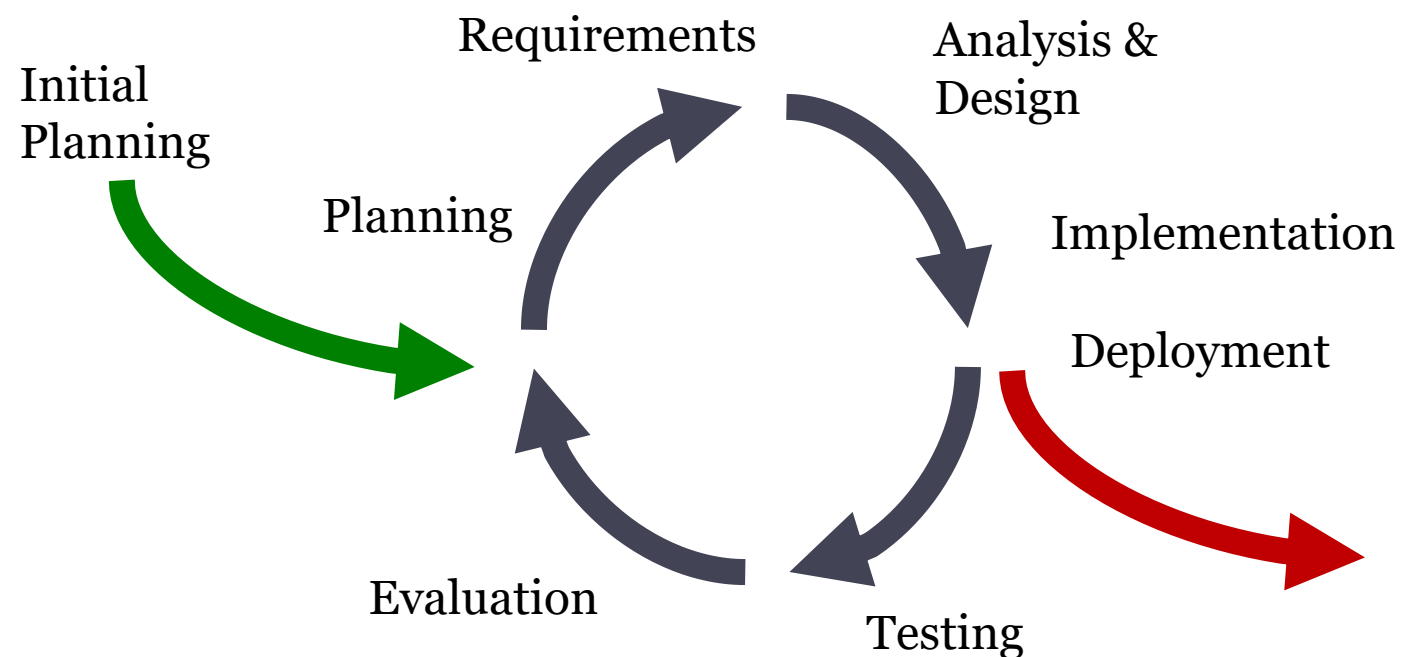
Software implemented but unused



Iterative Models

Based on Prototypes

Risk assessment after each iteration



Agile methodologies Overview

Agile methodologies

Lots of variants

RAD (www.dsdm.org, 95)

SCRUM (Sutherland & Schwaber, 95)

XP - eXtreme Programming (Beck, 99)

Feature driven development (DeLuca, 99)

Adaptive software development (Highsmith, 00)

Lean Development (Poppendieck, 03)

Crystal Clear (Cockburn, 04)

Agile Unified Process (Ambler, 05)

...

Agile methods

Agile Manifesto (www.agilemanifesto.org)

Individuals and
interactions

over

Processes and
Tools

Working
Software

over

Comprehensive
Documentation

Customer
Collaboration

over

Contract
Negotiation

Responding
to change

over

Following a
Plan

Agile methods

Feedback

Changes of code are OK during development

Minimize risk

Software in short intervals

Iterations of days

Each iteration takes all the development cycle

Some agile principles (XP)

1. Adapt to change
2. Testing
3. Pair programming
4. Refactoring
5. Simple design
6. Collective code ownership
7. Continuous integration
8. On-site customer
9. Small releases
10. Sustainable pace
11. Coding standards

Adopt change

After each iteration, update plans

Requirements through user stories

Short descriptions (size of a card)

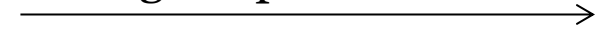
Goals ordered by using according to priority

Risk and resources estimated by developers

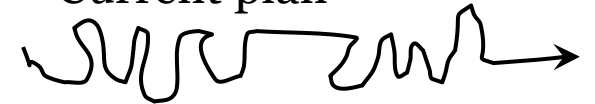
User stories = acceptance testing

Welcome changing requirements

Original plan



Current plan



TDD - Test driven development

Write a test before coding

Initially, code will fail

Goal: pass the test

Result:

- Automated set of tests

- Easier refactoring



Different types of testing

Unit testing

Check each unit separately

Integration testing

Smoke testing

Acceptance testing

Check with user stories

Performance/capacity testing:

Load testing

Regression testing

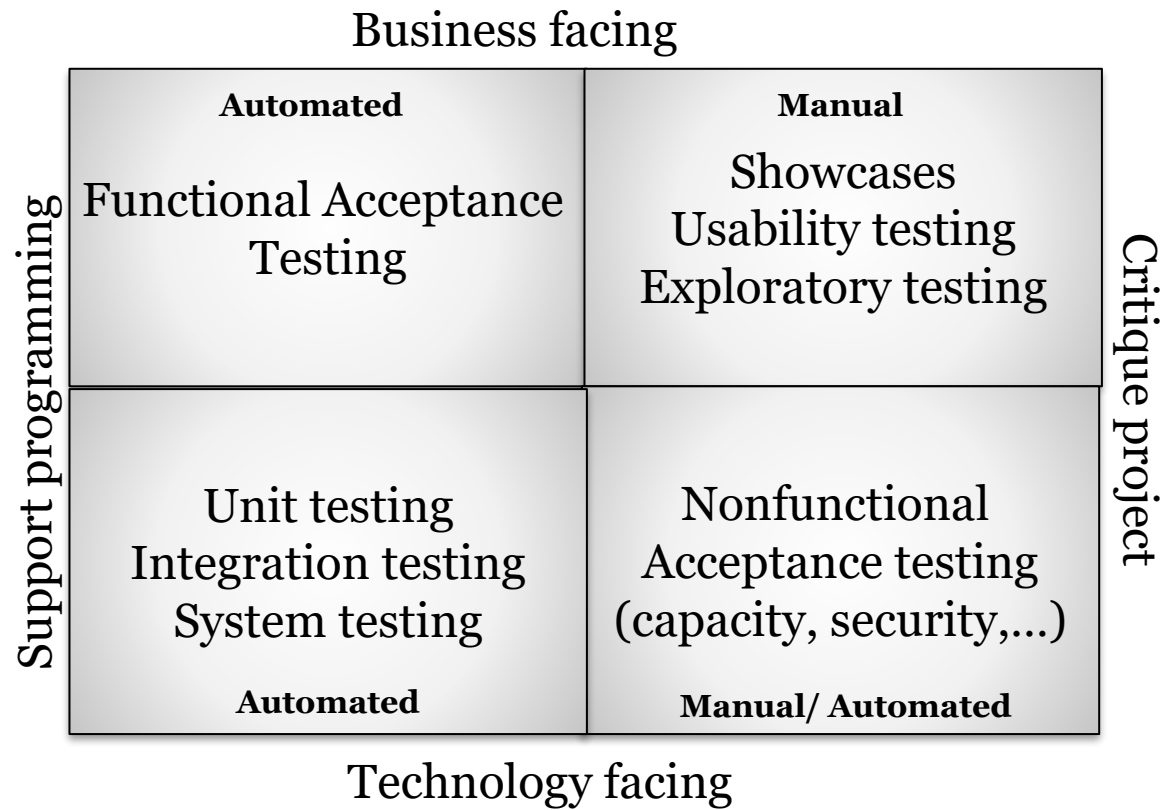
Check that new changes don't introduce new bugs, or *regressions*

Types of testing

Project vs programming

Business vs technology

Manual vs automatic



Acceptance testing

Behavior-driven development (BDD)

Tests come from user stories

They can be written collaboratively with the client

Tools: Cucumber, JBehave, Specs2,...

Tests act as contracts

Can also be used to measure progress

Feature: Find courses

Improve course management

Students should be able to search courses

Scenario: Search by subject

Given there are 240 courses without "Biology" subject

And there are 2 courses A001, B205 with subject "Biology"

When I search subject "Biology"

Then I obtain the courses:

| Code |

| A001 |

| B205 |

Testing: FIRST Principles

F - Fast

Execution of (subsets of) tests must be quick

I - Independent:

No tests depend on others

R - Repeatable:

If tests are run N times, the result is the same

S - Self-checking

Test can automatically detect if passed

T - Timely

Tests are written at the same time (or before) code

Test doubles

Dummy objects:

Objects that are passed but not used

Fake objects: Contain a partial implementation.

Stubs: contain specific answers to some requests

Spies: *stubs* that record information for debugging

Mocks: mimic the behavior of the real object

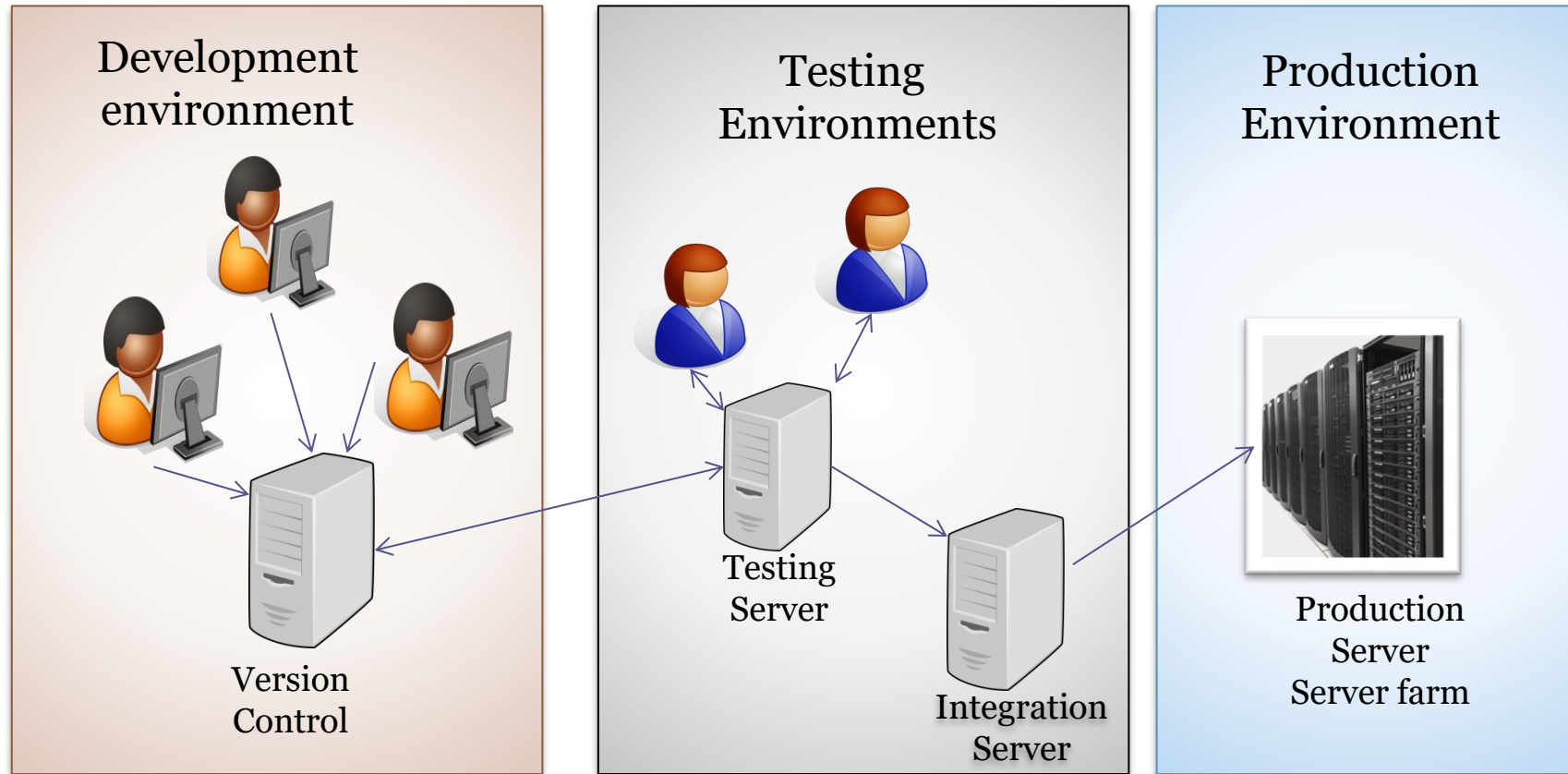
Mocks may contain assertions about the order/number of times methods are called

Fixtures: Tools that support tests

Testing databases, some files, etc.



Environments



A staging environment is also usually employed

Pair programming & Code reviews

2 software engineers work together

Driver manages keyboard and creates implementation

Observer identifies failures and gives ideas

Roles are exchanged after some time

Pull requests: Before accepting changes, code can be reviewed



Simplicity

Favor Simple design

Reaction to Big Design Up Front

Obtain the simpler design that works

Automated documentation

JavaDoc and similar tools



Refactoring

Improve design without changing functionality

Simplify code (eliminate redundant code)

Search new opportunities for abstraction

Regression testing

Based on the test-suite



Collective ownership of code

Code belongs to the project, not to some engineer

Engineers must be able to browse and modify any part of the code

Even if they didn't wrote it

Avoid code fragments that only one person can modify



Continuous Integration

Frequently integrating one's new or changed code with existing code repository

Running all unit and integration tests

Merge all developer working copies

Goals

Help Test Driven Development

Maintain all programmers code up to date

Avoid integration hell



Continuous Integration

Best practices:

- Maintain code repository

- Automate the build

- Make the build self testing

- Everyone commits to the baseline

- Every commit should be built

- Keep the build fast

- Test in a clone of the production environment

- Make it easy to get the latest deliverables

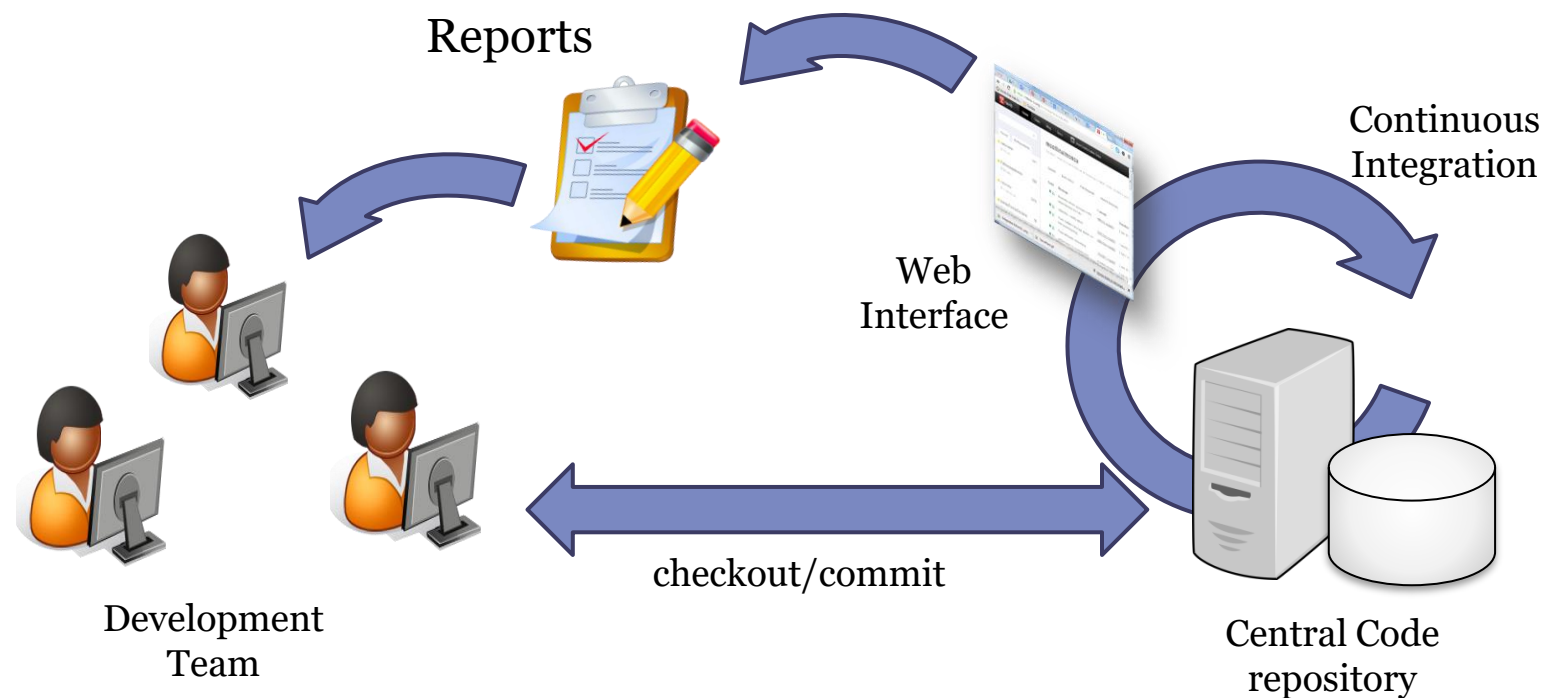
- Everyone can see the results of the latest build

- Automate deployment

Continuous integration

Continuous integration tools

Github Actions, Travis, Hudson, Jenkins, Bamboo, ...



On-place customer

Customer available to clarify user stories and help taking critical business decisions

Advantages

Developers don't do guesses

Developers don't have to wait for decisions

Improves communication



Continuous delivery

Small releases

Small enough while offering value to the user

Obtain feedback soon from client

Delivery models

Try to release something every night/week...

Continuous and automated delivery



Sustainable pace

Avoid extra-work loads

40h/week = 40h/week

Tired programmers write bad code

It will slow the development at long time



Clean code & code conventions

Facilitate code refactoring by other people

Use good practices

Code styles and guidelines

Avoid code smells

Software craftsmanship manifest

Clean Code (Robert C. Martin)

<https://manifesto.softwarcraftsmanship.org/>



Source: Clean Code. Robert Martin

Some agile methods

Scrum

Project/people management

Divide work in sprints

15' daily meetings

Product Backlog

Kanban

Lean model

Just in Time Development

Limit workloads



Configuration management

Configuration Management

Different software versions

New or different functionalities

Issues and bugs management

New execution environments

Configuration management

Manage software evolution

System changes = team activities

Imply cost and effort

Version control

Systems that manage different code versions

Be able to Access all the system versions

Easy to rollback

Differences between versions

Collaborative development

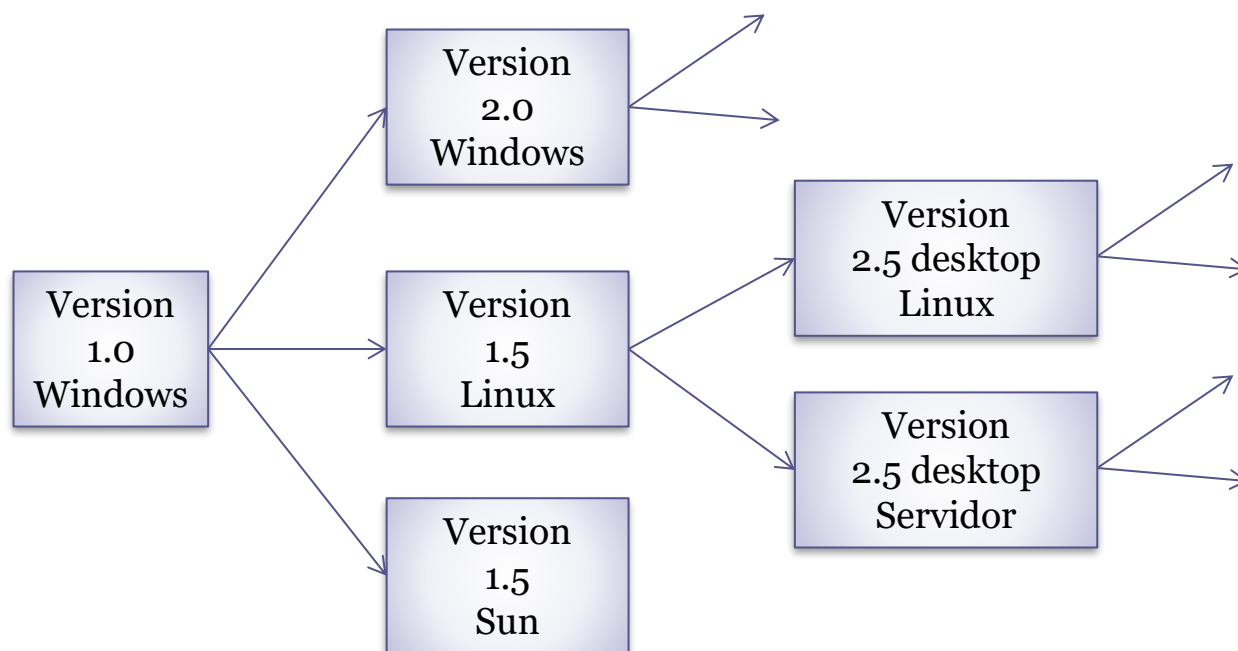
Branch management

Metadata

Author of a version, update date, who to blame, etc.

Baseline

Baseline: Software which is the object of configuration management



Releases and versions

Version: instance of a system which has a different functionality to other instances

Release (deliverable): instance of a system which is distributed to external people outside to development team.

It can be seen as a final product at some point



Version naming - some conventions

Pre-alpha

Before testing

Alpha

During testing

Beta (or prototype)

Testing made by some users

Beta-tester: user that does the testing

Release-candidate

Beta version that could become final product

Other schema namings

Using some attributes

Date, creator, language, client, state,...

Recognizable Names

Ganimede, Galileo, Helios, Indigo, Juno,...

Precise Pangolin, Quantal Quetzal,...

Semantic Versioning (<http://semver.org>)

MAJOR.MINOR.PATCH (2.3.5)

MAJOR: changes incompatible with previous versions

MINOR: new functionality compatible with previous versions

PATCH: Bugfix compatible with previous versions

Version 0 (unstable)

Pre-releases (names added at the end): 2.3.5-alpha

Publishing releases

A *release* implies functionality changes

Planning

Publishing a release has costs

Usually, current users don't want new releases

External factors:

Marketing, clients, hardware, ...

Agile model: frequent *releases*

Continuous integration minimizes risk

Publishing Releases

A release is more than just software

Configuration files

Some needed data files

Installation programs

Documentation

Publicity and packaging

Continuous delivery

Continuous delivery

Frequent releases to obtain feedback as soon as possible

TDD & continuous integration

Deployment pipeline

Advantages:

Embrace change

Minimize integration risks



Wabi-sabi philosophy

Accept imperfection

Software that is not finished: Good enough

DevOps

Merge ***development and operations***

Cultural change where the same team participates in:

Code: Development and code review, continuous integration

Build: Version control, building and integration

Test

Package: Artifact management

Release: version automation

Configuration and management

Monitorization: performance, user experience

Construction tools

Construction languages

Configuration languages

Resource definitions (JSON, XML, Turtle)

Examples: .travis.yml, package.json, pom.xml

Scripting languages

Shell/batch scripts

Programming languages

Examples: Java, Javascript, ...

Visual languages

Examples: scratch, blender, ...

Formal

Examples: B-trees, Z language, OCL, ...

Coding aspects

Naming conventions

Important for other programmers, maintainers...

Classes, types, variables, named constants, ...

Error handling

Source code organization

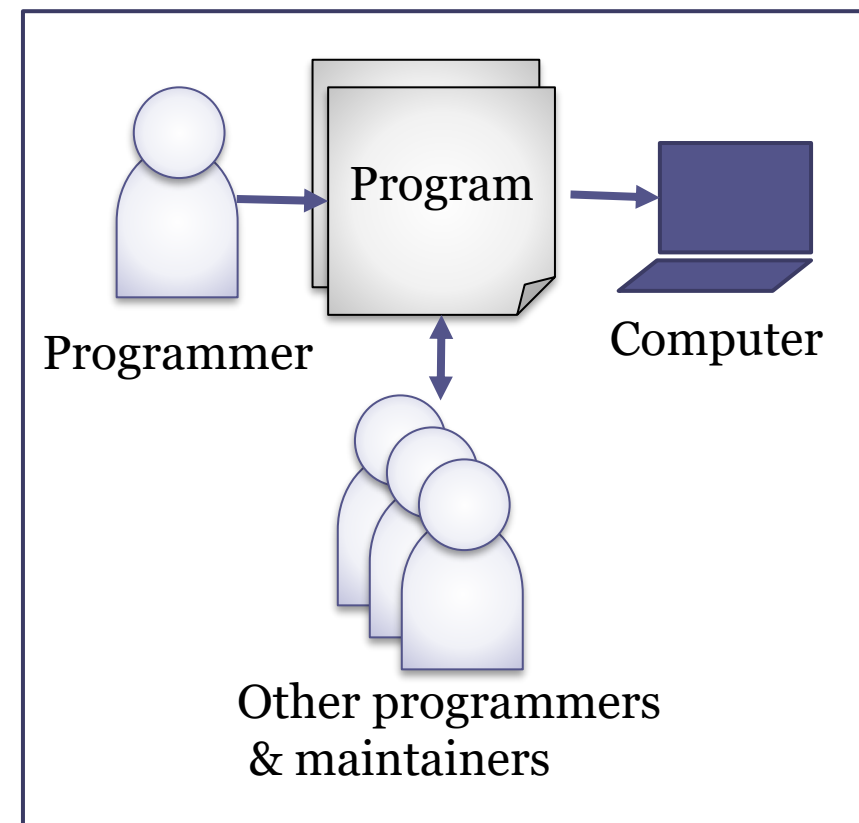
Packages, folders, ...

Dependencies

Libraries imported

Code documentation

Javadocs, jsdoc...



Testing

Unit testing

Integration testing

Load testing

Regression testing

...

Best practice:

Separate testing code and dependencies from production code

Construction for reuse

Parameterization

Add parameters

Common error: magical numbers in code

Configuration/resource files

Conditional compilation

Encapsulation

Separate interface from implementation

Common error: internal parts public in libraries

Packaging

Common error: manual tasks for packaging

Documentation

API documentation

Construction reusing

Selection of reusable units

Externally developed components (COTS, FOSS)

Handling dependencies

<See later>

Handling updates

What happens when other libraries are updated?

Legal issues

Can I really use that library?

For commercial software?

Be careful with GNU libraries

Is the library well maintained?

Construction tools

Text editors

vi, emacs, Visual Studio Code, Sublime,....

Integrated Development Environments (IDEs)

Examples: IntelliJ, Eclipse

Graphical User Interface (GUI) builders

Android Studio UI Editor, QtEditor,...

Quality assurance (QA) tools

Test, analysis, ...<See next slide>

Software Quality Assurance

Tests

- xUnit, test frameworks (mocha)

- Assertion languages (chai)

- Test coverage tools

Assertions

- Pre-conditions asserted on methods

Inspections & code reviews

- Pull requests with code reviews

Code Analysis tools

- <See next slide>

Code analysis tools

Static vs dynamic code analysis

Without running the code (or at runtime)

Examples: PMD, SonarCube,... (Codacy)

Debuggers

Interactive vs static, Tracers & logging

Profilers

Information about resource usage

Memory, CPU, method calls, etc.

Test coverage tools

Report which lines of code have been run during tests

Program slicing

Program fragment (slice) that has been run

Examples: CodeSurfer, Indus-kaveri,...

Version Control Systems

Version control

Definitions

Repository: where changes are stored

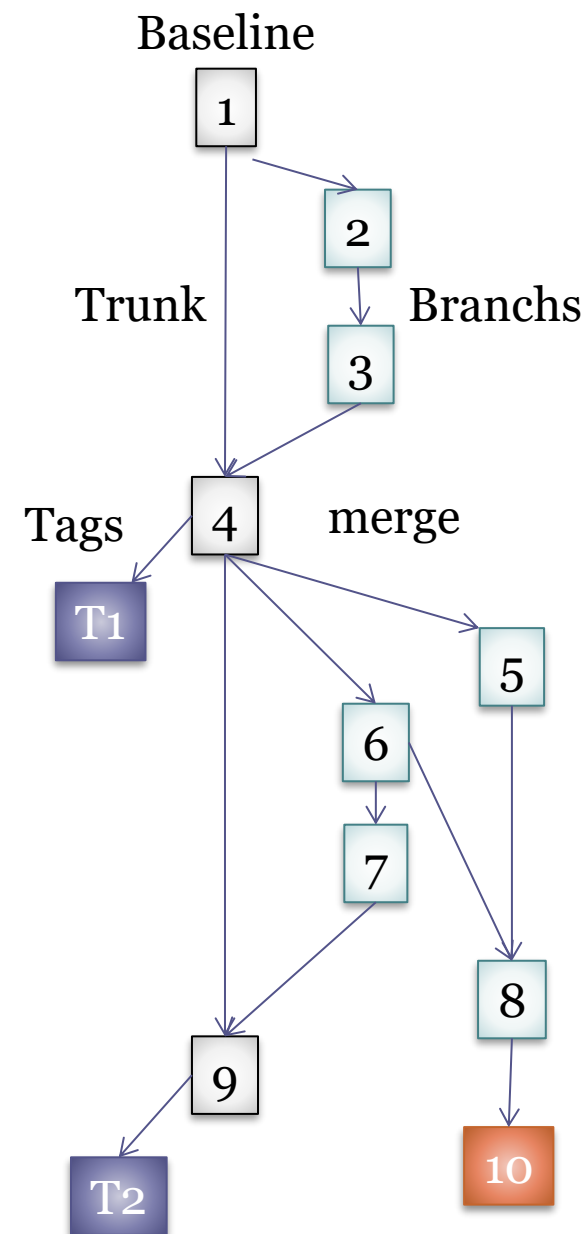
Baseline: Initial version

Delta: changes from one version to other

Trunk (master): Main branch in a system

Branch: deviation from main branch

Tag: Marks a line of versions



Version control

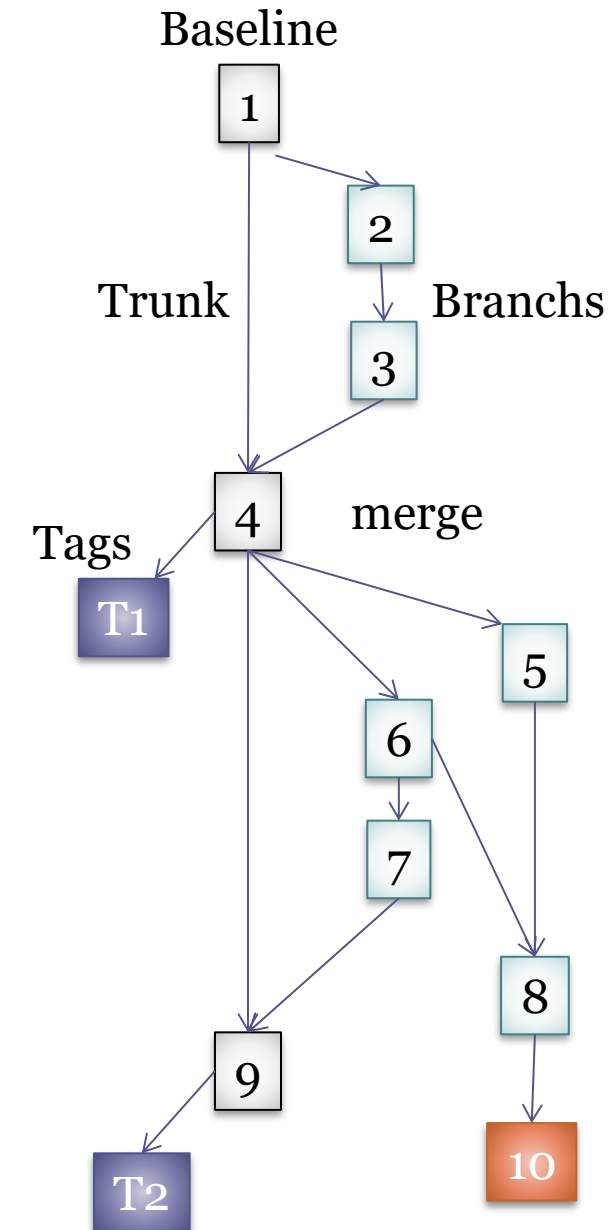
Definitions

Checkout: Working Local copy from a given branch

Commit: Introduce current changes in the control version system.

Merge: Combine two sets of changes

Branching styles: by feature, by team, by version



Version control

2 types

Centralized

Centralized repository for all the code

Centralized administration

CVS, Subversion, ...

Distributed

Each user has its own repository

Git, Mercurial

Git

Designed by Linus Torvalds (Linux), 2005

Goals:

Applications with large number of source code files

Efficiency

Distributed work

Each development has its own repository

Local copy of all the changes history

It is possible to do commits even without internet connection

Support for non-linear development (branching)

More information:

<http://rogerdudler.github.com/git-guide/>



Local components

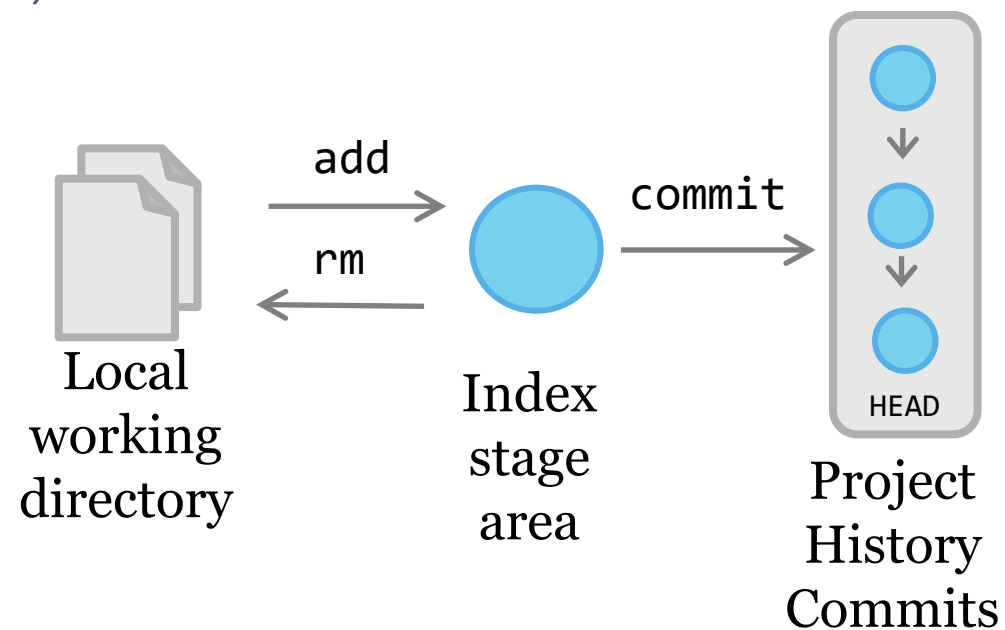
3 local components:

Local working directory

Index (stage area). Also called cache

Project history: Stores versions or commits

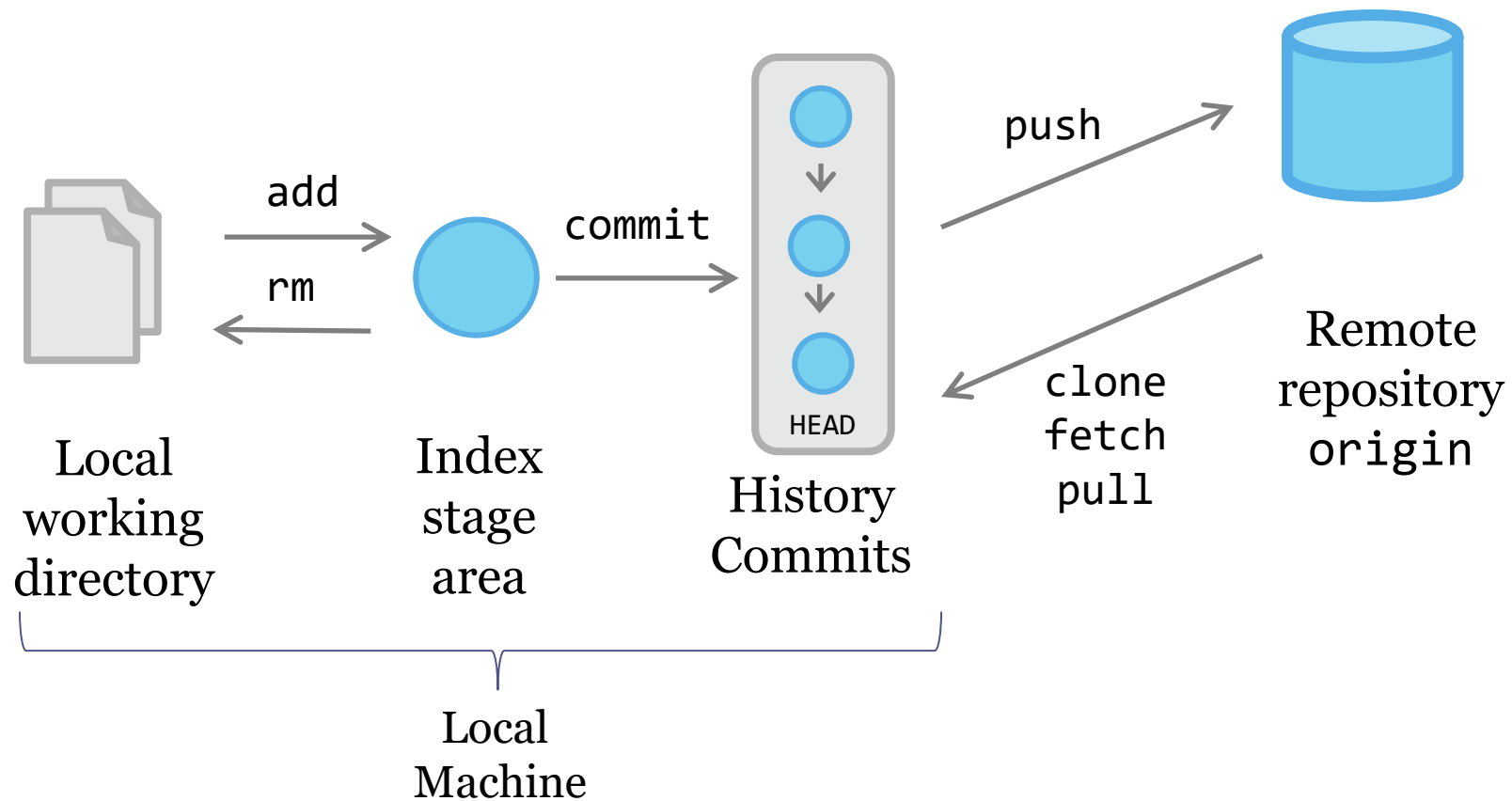
HEAD (most recent version)



Remote repositories

Connect with remote repositories

origin = initial



Branches

Git facilitates branch management

master = initial branch

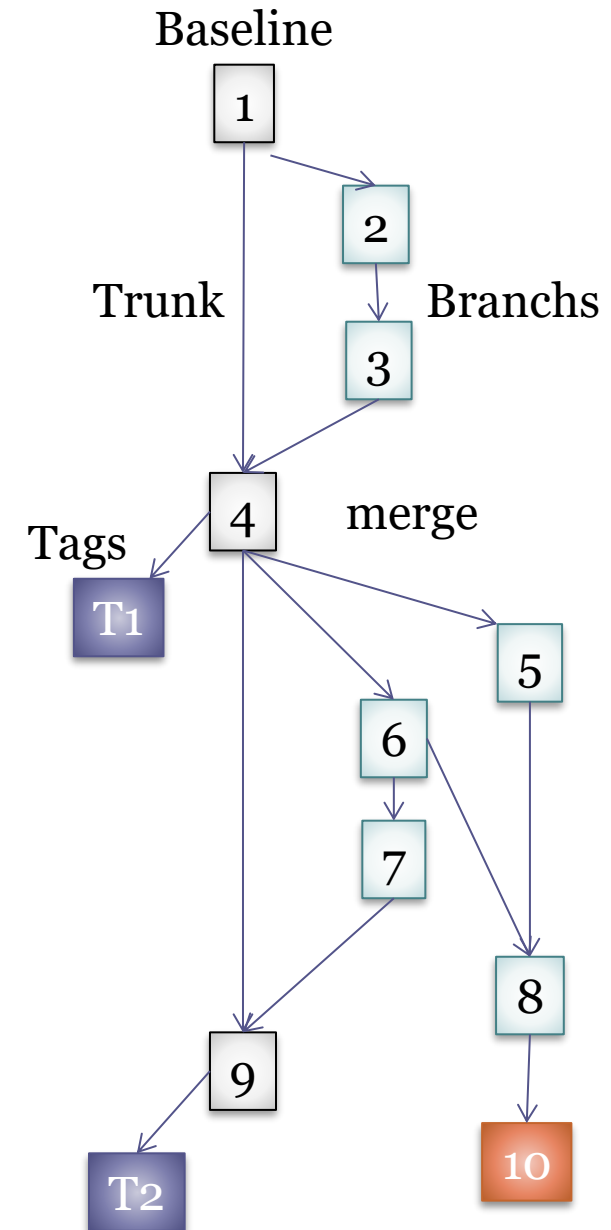
Operations:

Create branches (*branch*)

Change branch (*checkout*)

Combine (*merge*)

Tag branches (*tag*)



Branching patterns

Git-flow

Develop branch as mainline

Github-flow

Everything in master is deployable

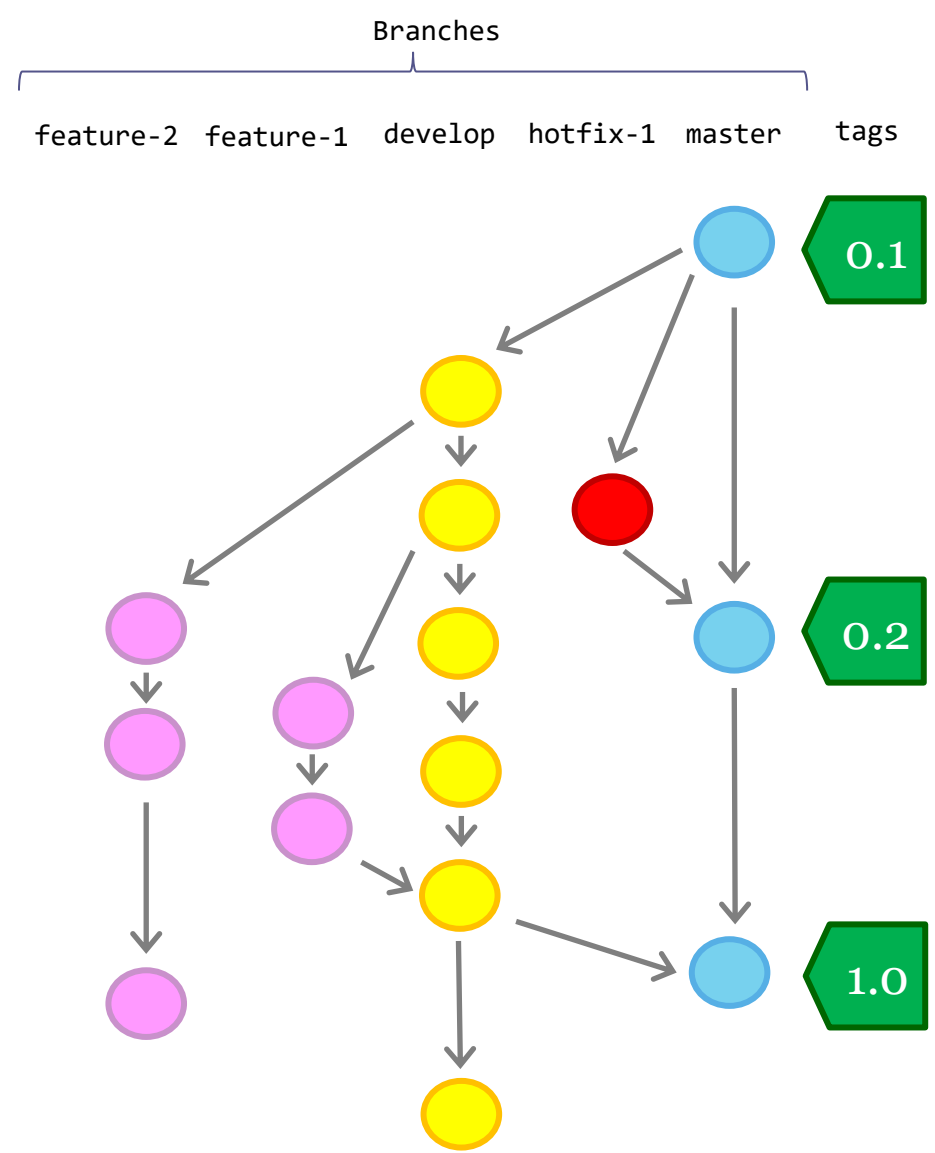
No hotfix branch

Promotes pull-requests

Trunk-based development

Everything in trunk (master)

Short-lived feature branching



Dependency management

Dependency management

Library: Collection of functionalities used by the system that is being developed

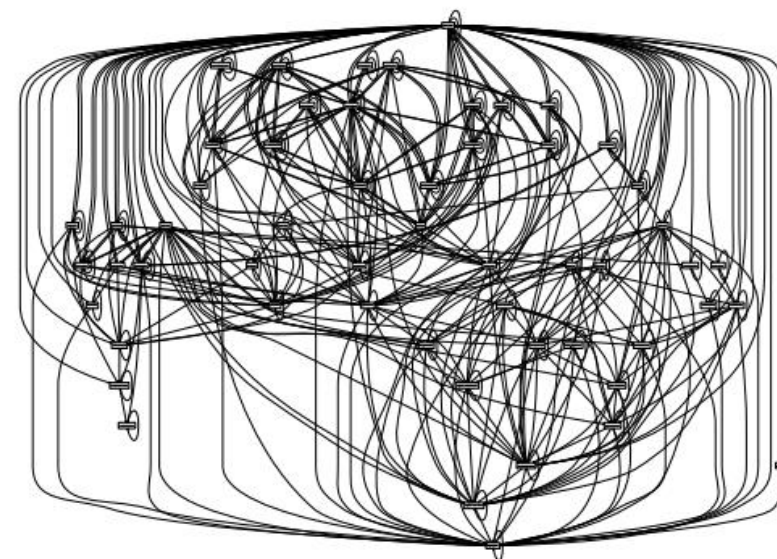
System depends on that library

Library can depend on other libraries

Library can evolve

Incompatible versions appear

Dependency graph



Mozilla Firefox dependency graph

Source: The purely functional deployment model. E. Dolstra (PhdThesis, 2006)

Dependency graph

Graph $G = (V, E)$ where

V = Vertex (components/packages)

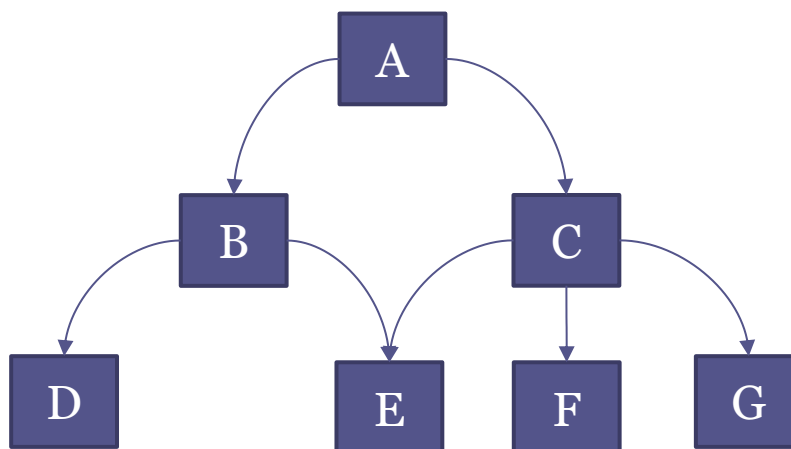
E = Edges (u, v) that indicate that u depends on v

CCD metric (cumulative component dependency)

Sum of every component dependency

Each component depends on itself

In the example:
 $CCD = 7 + 3 + 4 + 1 + 1 + 1 + 1 = 18$



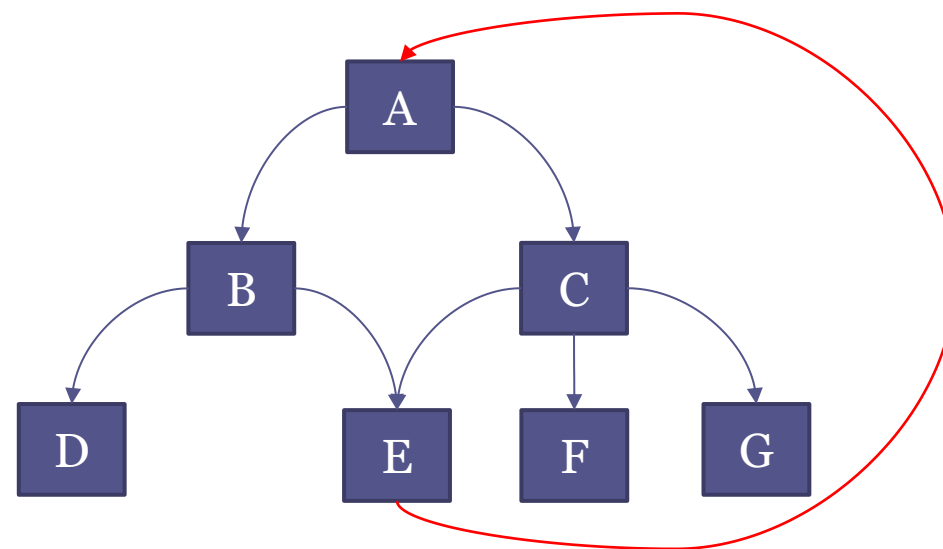
Cyclic dependencies problem

The dependency graph should not have cycles

Adding a cycle can damage CCD

Example:

$$\text{CCD} = 7+7+7+1+7+1+1=31$$



Dependency management

Different models

Local installation: libraries are installed for all the system

Example: Ruby Gems

Embed external libraries in the system (version control)

Ensures a correct version

External link

External repository that contains the libraries

Depends on Internet and on library evolution

Build automation

Tools that automate building and deployment

Organize different tasks

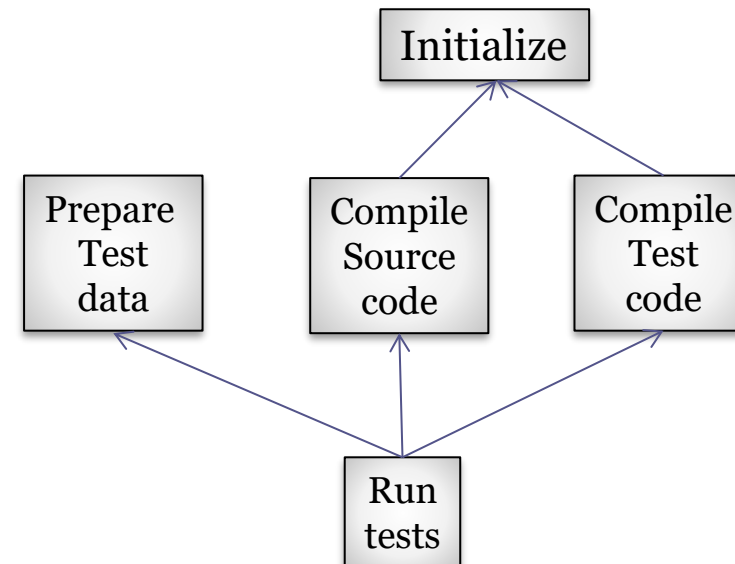
Compile, package, install, deploy, etc.

Dependencies between tasks

Must check:

- Run all prerequisites

- Run them once



Build automation

Automate building tasks

Some quality attributes:

Correctness:

- Avoid mistakes (minimize "*bad builds*")

- Eliminate repetitive and redundant tasks

Simplicity: Handle complexity

Automation & releasability

- Have history of builds and releases

- Continuous integration

Cost

- Save time & money

"Never send a human to do a machine's job"
G. Hohpe

When to build?

On-demand

A user running a script at the command line

Scheduled

Automatically run at certain hours

Continuous integration server

Example: nightly builds

Triggered

At every commit to a version control system

Continuous integration server linked to version control system

Build Automation Tools

makefile (C, C++)

Ant (Java)

Maven (Java)

SBT (Scala, JVM languages)

Gradle (Groovy, JVM languages)

rake (Ruby)

npm, grunt, gulp (Javascript)

cargo (Rust)

etc.

Automate building

make: Included in Unix

Product oriented

Declarative language based on rules

When the Project is complex, configuration files
can be difficult to manage/debug

Several versions: BSD, GNU, Microsoft

Very popular in C, C++, etc.

Automate building

ant: Java Platform

Task oriented

XML syntax (build.xml)

Automate building

maven: Java Platform

Convention over configuration

Manage project lifecycle

Dependency management

XML syntax (pom.xml)

Automate building

Embedded languages

Domain specific languages embedded in higher level ones

Great versatility

Examples:

`gradle` (Groovy)

`sbt` (Scala)

`rake` (Ruby)

`Buildr` (Ruby)

`gulp` (Javascript)

...

New tools

Pants (Foursquare, twitter)

<https://pantsbuild.github.io/>

Bazel (Google)

<http://bazel.io/>

Buck (Facebook)

<https://buckbuild.com/>

Maven

Maven

Build automation tool

Describes how software is built

Describes software dependencies

Principle: Convention over configuration



Jason van Zyl
Creator of Maven

Maven

Typical development phases:

`clean, compile, build, test, package, install, deploy`

Module identification

3 coordinates: Group, Artifact, Version

Dependencies between modules

Configuration: XML file (Project Object Model)

`pom.xml`

Maven

Artifact repositories

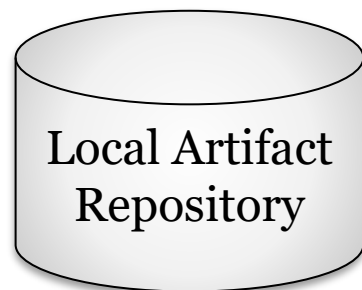
Store different types of artifacts

JAR, EAR, WAR, ZIP, plugins, etc.

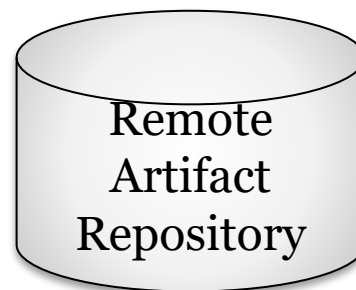
Every interaction is made through the repository

No relative paths

Share modules between development teams



`<user>/ .m2/repository`



Maven Central

Maven Central

Public repository of projects

Over 1 mill GAV

≈ 3000 new projects each month (GA)

≈ 30000 new versions each month(GAV)*

 The Central Repository

<http://search.maven.org/>

Other repositories:

<https://bintray.com/>

* Source: <http://takari.github.io/javaone2015/still-rocking-it-maven.html>

POM - Project Object Model

XML syntax

Describes a project

Name and version

Artifact type (jar, pom, ...)

Source code localizations

Dependencies

Plugins

Profiles

Alternative build configurations

Inheritance structure

Reference: <https://maven.apache.org/pom.html>

POM - Project Object Model

Inheritance structure

Super POM

Maven's default POM

All POMs extend the Super POM unless explicitly said

parent

Declares the parent POM

Dependencies and properties are combined

Maven

Project identification

GAV (Group, Artifact, Version)

Group: grouping identifier

Artifact: Project name

Version: Format {Major}.{Minor}.{Maintenance}

It is possible to add "-SNAPSHOT" (in development)

```
<project xmlns="http://maven.apache.org/POM/4.0.0"
          xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
          xsi:schemaLocation="http://maven.apache.org/POM/4.0.0
                              http://maven.apache.org/xsd/maven-4.0.0.xsd">
  <modelVersion>4.0.0</modelVersion>
  <groupId>es.uniovi.asw</groupId>
  <artifactId>censusesN</artifactId>
  <version>0.0.1</version>
  <name>censusesN</name>
  ...
</project>
```


Maven

Folder structure

Maven uses a conventional structure

src/main

src/main/java

src/main/webapp

src/main/resources

src/test/

src/test/java

src/test/resources

...

Output directory:

target

Maven Build life cycle

3 built-in lifecycles

default

Project deployment

clean

Project cleaning

site

Project's site documentation

Each life cycle has some specific phases

clean

Clean compiled code and other stuff

3 phases

pre-clean

clean

post-clean

default lifecycle

Compilation, testing and deploying
Some phases

```
validate  
initialize  
generate-sources  
generate-resources  
compile  
test-compile  
test  
package  
integration-test  
verify  
install  
deploy
```

site lifecycle

Generates Project's site documentation

Phases

```
pre-site  
site  
post-site  
site-deploy
```

Maven

Automatic dependency management

GAV identification

Scopes

compile

test

provide

Type

jar, pom, war,...

```
...  
<dependency>  
<groupId>commons-cli</groupId>  
<artifactId>commons-cli</artifactId>  
<version>1.3</version>  
</dependency>  
...
```

Maven

Automatic dependency management

Dependencies are downloaded

Stored in a local repository

We can create intermediate repositories (proxies)

Examples: common artifacts for some company

Transitivity

A depends on B

B depends on C

⇒ If a system depends on A

Both B and C are downloaded

Maven modules: aggregation

Big projects can be decomposed in subprojects

Each Project creates one artifact

Contains its own pom.xml

Parent Project groups modules

```
<project>
  ...
  <packaging>pom</packaging>
  <modules>
    <module>extract</module>
    <module>game</module>
  </modules>
</project>
```


Maven Plugins

Maven architecture based on plugins

2 types of plugins

`build`

`reporting`

List of plugins: <https://maven.apache.org/plugins/index.html>

Maven

Other phases and plugins

`archetype:generate` - Generates Project archetype

`eclipse:eclipse` - Generates eclipse project

`site` - Generates Project web site

`site:run` - Generates Project web site and starts server

`javadoc:javadoc` - Generates documentation

`cobertura:cobertura` - Reports code executed during tests

`checkstyle:checkstyle` - Check coding style

`spring-boot:run` - Run a spring application

npm

npm

Node.js package manager

Initially create by Isaac Schlueter

Later became Npm inc.

Default package manager for NodeJs

Manages dependencies

Allows scripts for common tasks

Software registry

Public or paid packages

Configuration file: package.json

npm configuration: package.json

Configuration file: package.json

npm init creates a simple skeleton

Fields:

```
{
  "name":           "...mandatory...",
  "version":        "...mandatory...",
  "description":    "...optional...",
  "keywords":       "...",
  "repository":     {... },
  "author":         "...",
  "license":        "...",
  "bugs":           {...},
  "homepage":       "http://. . .",
  "main":           "index.js",
  "devDependencies": { ... },
  "dependencies":   { ... }
  "scripts":        { "test": " ... " },
  "bin":            {...},
}
```

Note: Yeoman provides fully featured scaffolding

npm packages

Repository: <http://npmjs.org>

Installing packages:

2 options:

Local

```
npm install <packageName> --save (--save-dev)
```

Global

```
npm install -g <packageName>
```

npm dependencies

Dependency management

Local packages are cached at `node_modules` folder

Access to modules through: `require('...')`

Global packages (installed with `--global` option)

Cached at: `~/ .npm` folder

Scoped packages marked by `@`

npm commands and scripts

Npm contains lots of commands

start \approx node server.js

test \approx node server.js

ls lists installed packages

...

Custom scripts:

run-script <name>

More complex tasks in NodeJs

Gulp, Grunt

<https://docs.npmjs.com/cli-documentation/>