University of Oviedo

Universidad de Oviedo

EN
English

School of Computer Science

Software taxonomies
Patterns, styles, tactics,...

SOFTWARE
ARCHITECTURE

School of Computer Science

2025-26

Jose E. Labra Gayo

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: from product to 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

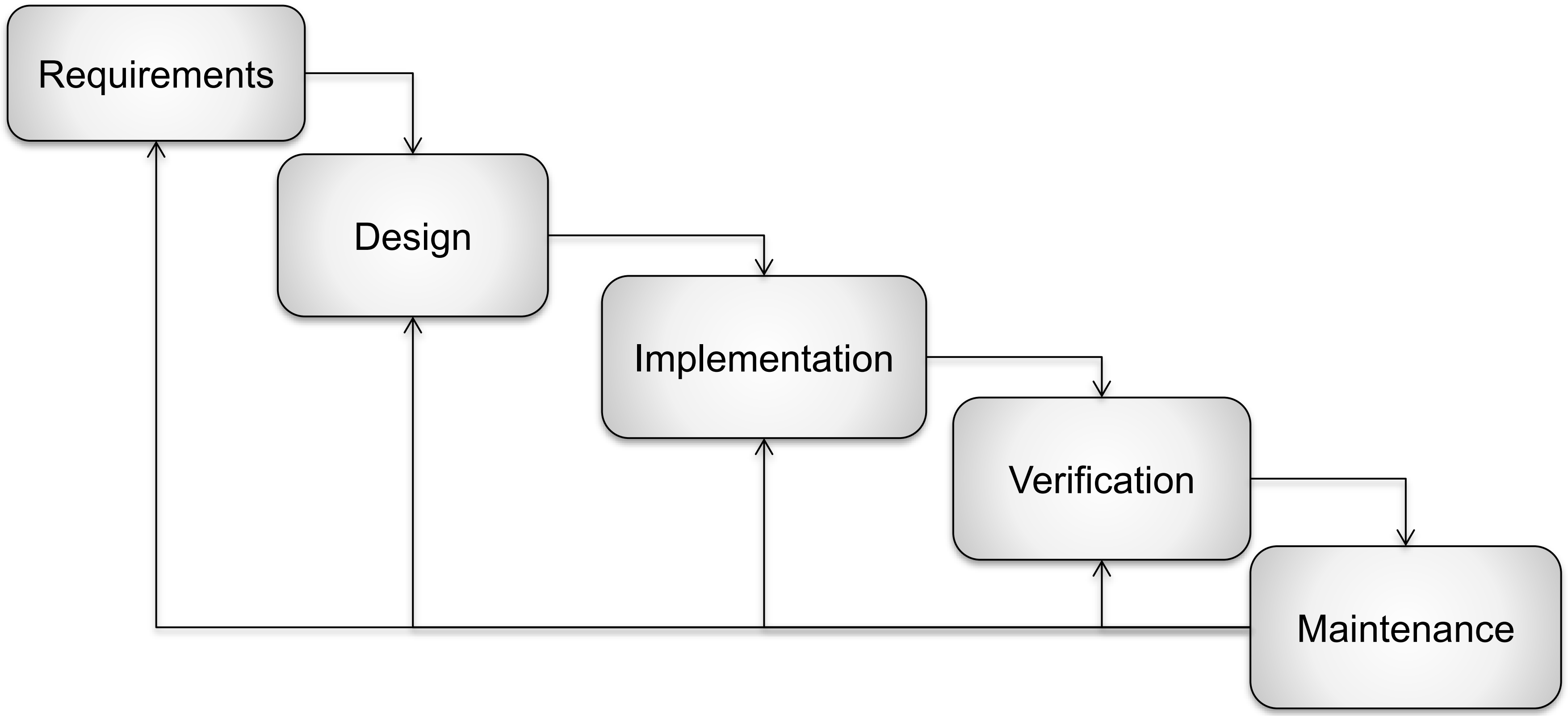
- Overview of methodologies
  - Traditional, iterative, agile
- Construction tools
  - Languages, tools, etc.

Incremental piecemeal

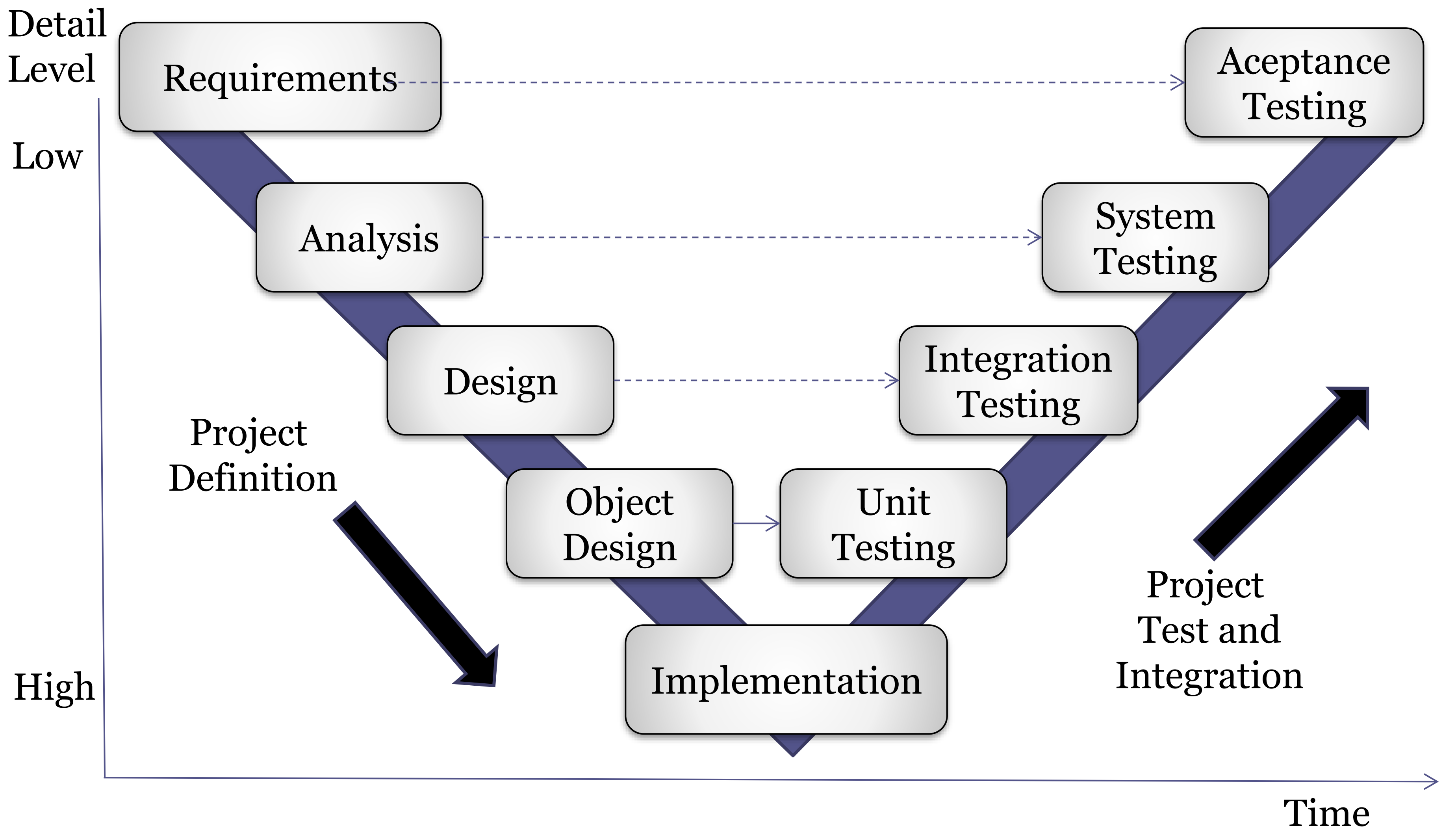
- Development by need
- Codification without following the architecture
- Throw-away software
- Budget constraints

Waterfall

Software Development Life Cycle (SDLC)
Waterfall model identified as antipattern in 1970s



V Model

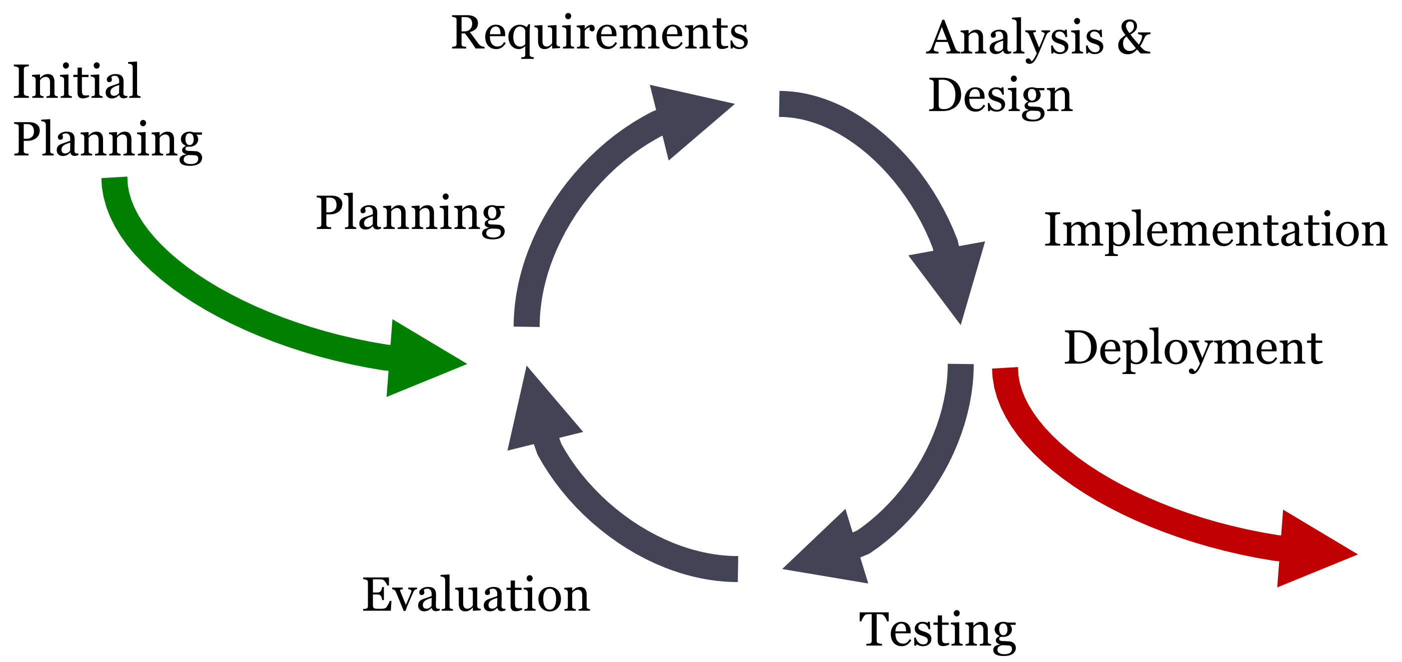

Detail
Level
Low
High
Requirements
Analysis
Design
Object Design
Implementation
Unit Testing
Integration Testing
System Testing
Aceptance Testing
Project Definition
Project Test and Integration
Time

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

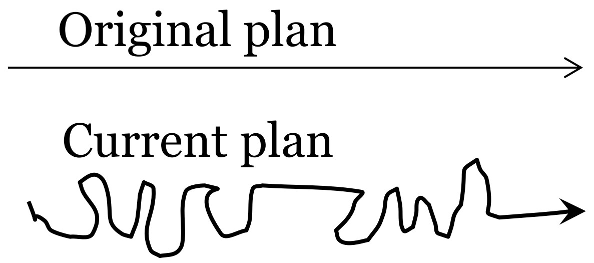
- Feedback
  - Changes of code are OK during development
- Minimize risk
  - Software in short intervals
  - Iterations of days
  - Each iteration takes all the development cycle

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



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

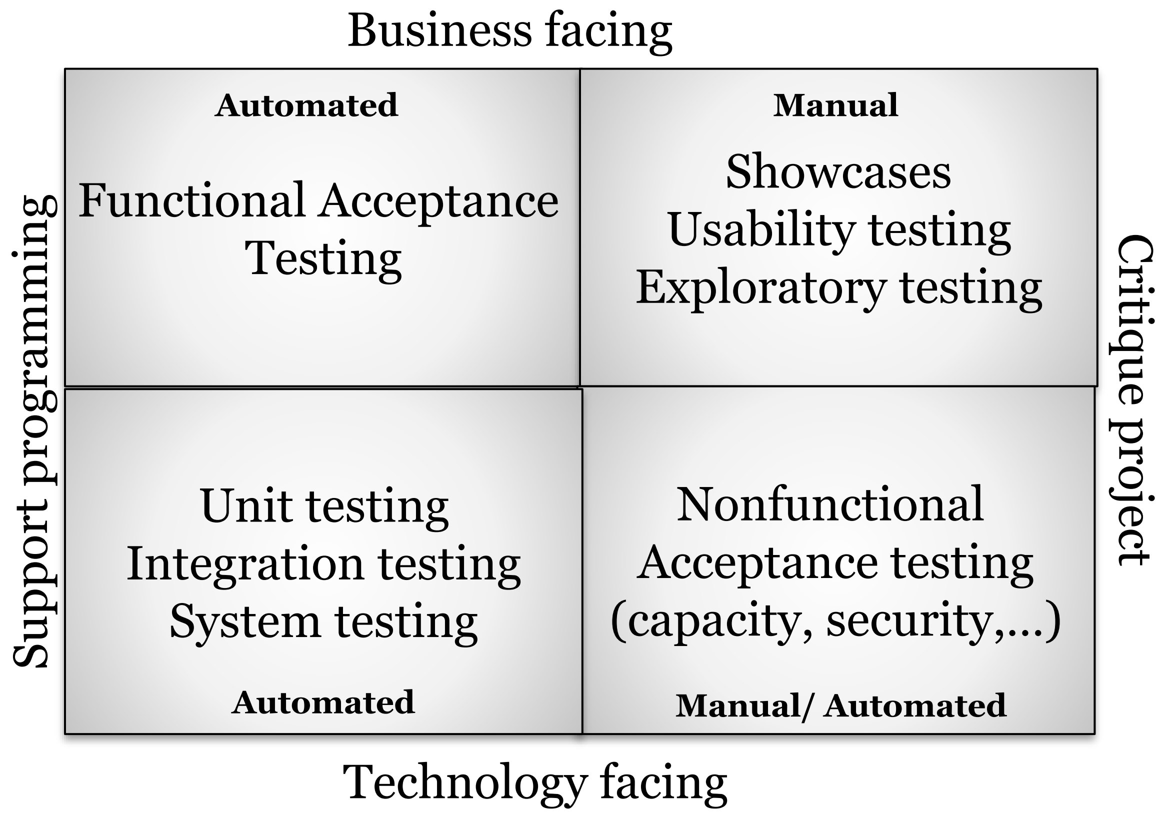
- Unit testing
  - Check each unit separately
- Integration testing
  - Smoke testing
- Acceptance testing
  - Check with user stories
- Performance/capacity testing:
  - Load testing
- Regression testing
  - Check that new changes don’t introduce new bugs, or *regressions*

Types of testing

Project vs programming

Business vs technology

Manual vs automatic



Source: Continuous delivery, J Humble, D. Farley, 2010

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

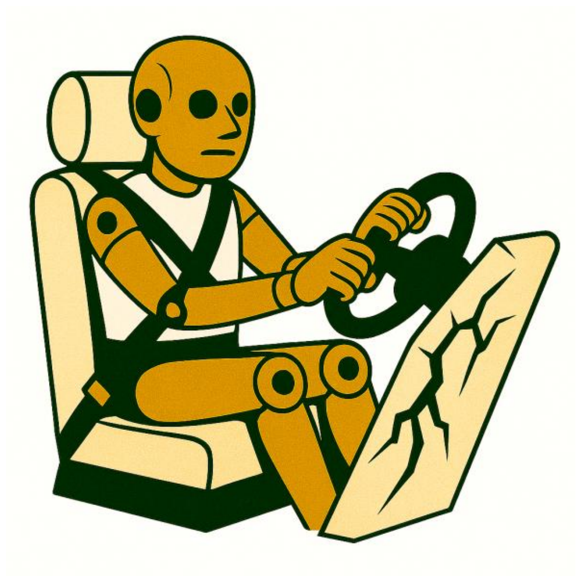
```
Feature: Find courses
  Improve course management
  Students should be able to search courses

  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

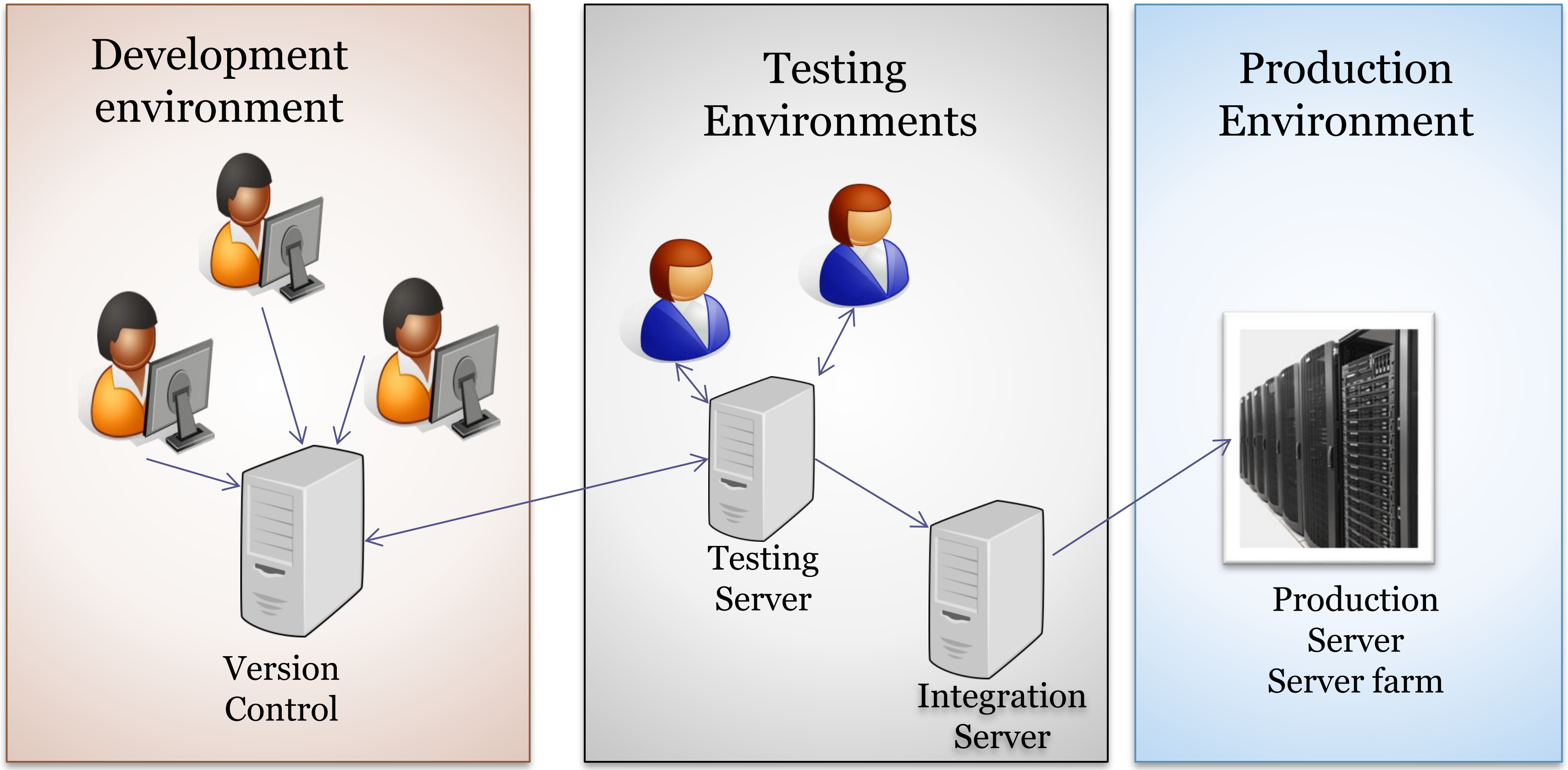
Fake objects*:* Contain a partial implementation.

- *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

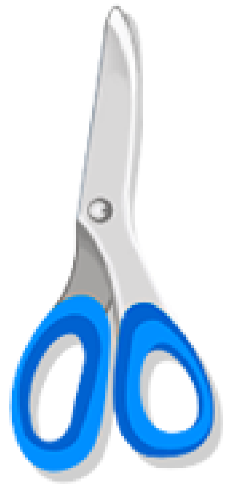


A staging environment is also usually employed

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 write 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

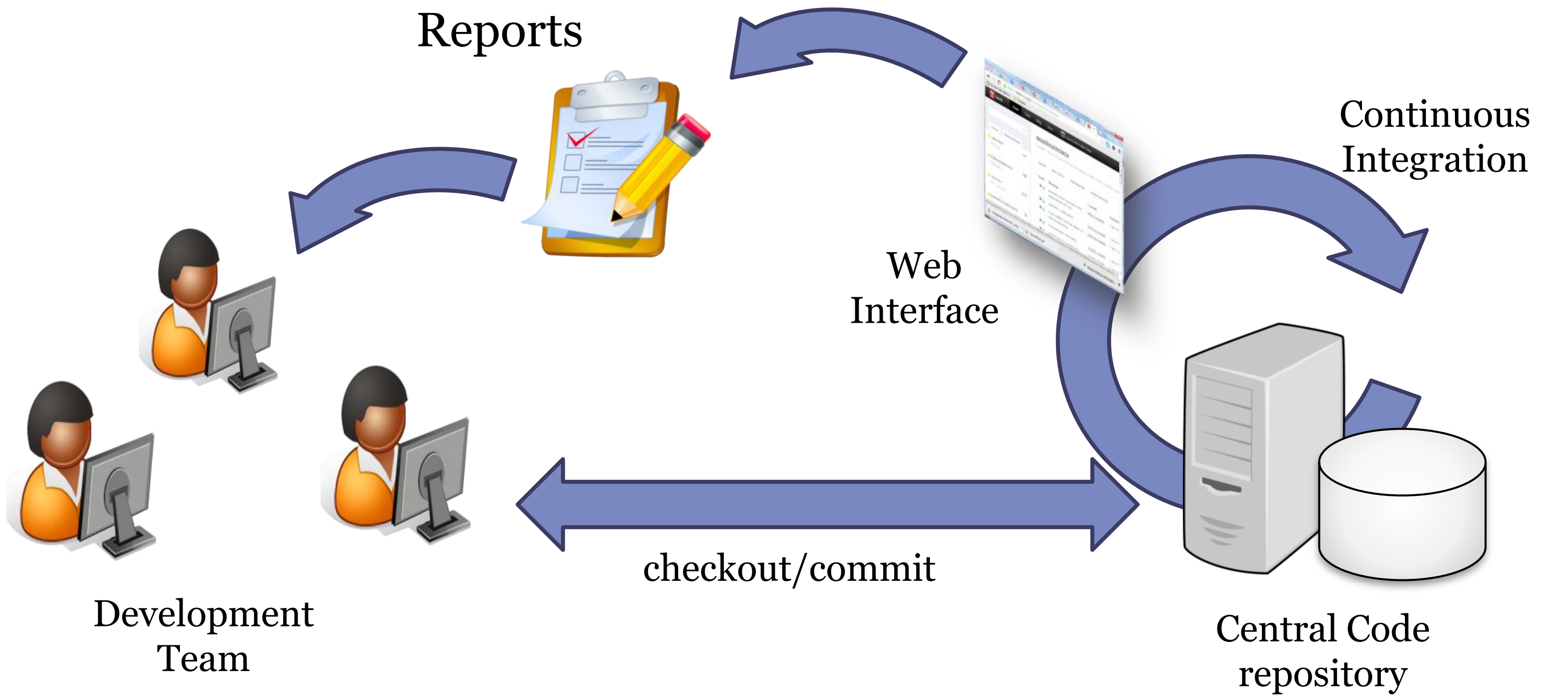
Best practices:

- 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, …



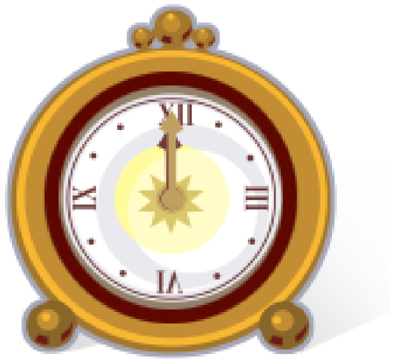
On-place customer

- 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

Continous 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 craftmanship manifest*
- *Clean Code (Robert C. Martin)*

https://manifesto.softwarecraftsmanship.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

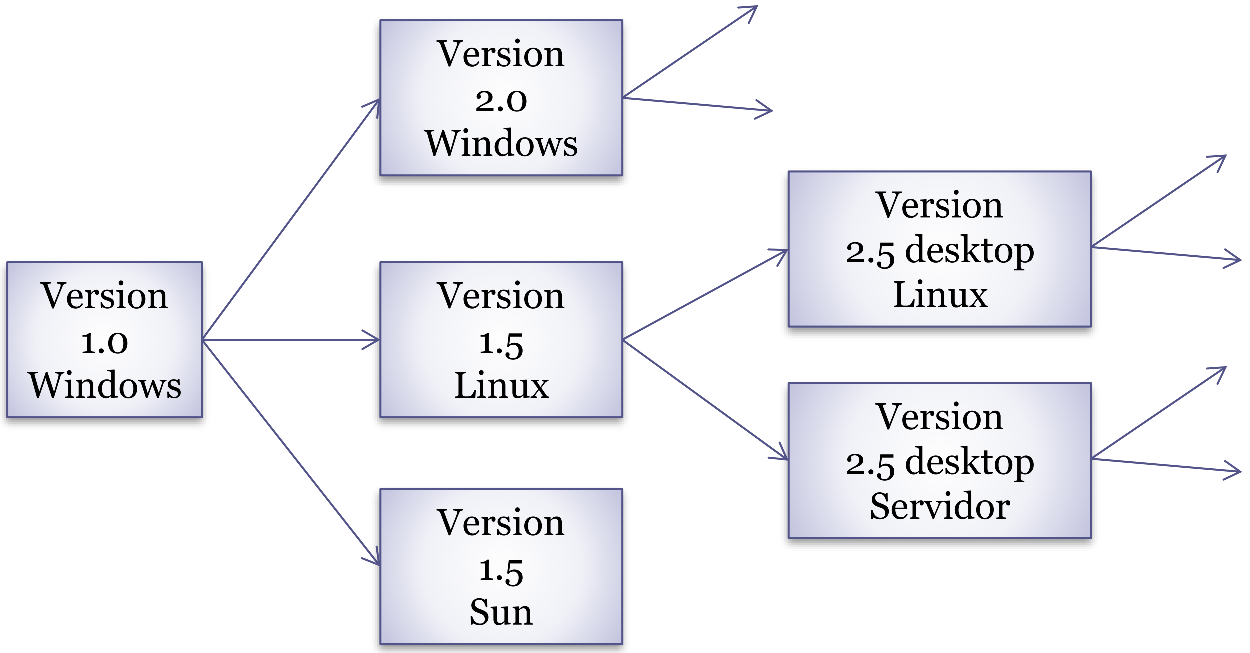
- Different software versions
  - New or different functionalities
  - Issues and bugs management
  - New execution environments
- Configuration management
  - Manage software evolution
  - System changes = team activities
  - Imply cost and effort

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 finnished: Good enough

DevOps

Merge ***dev**elopment and **op**eration**s***

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

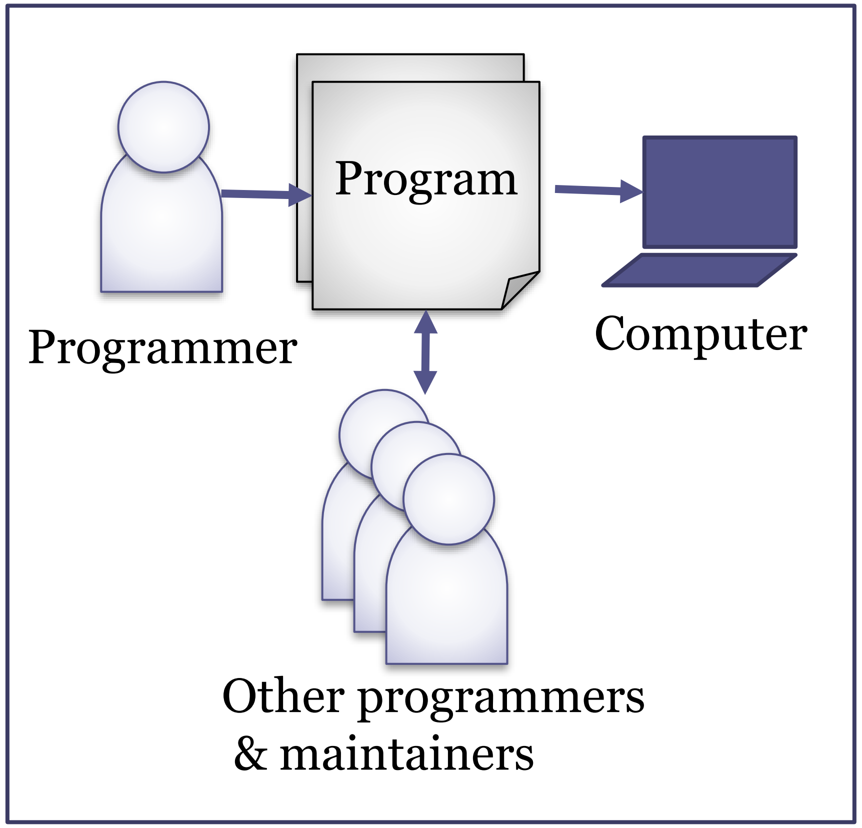
Construction tools

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

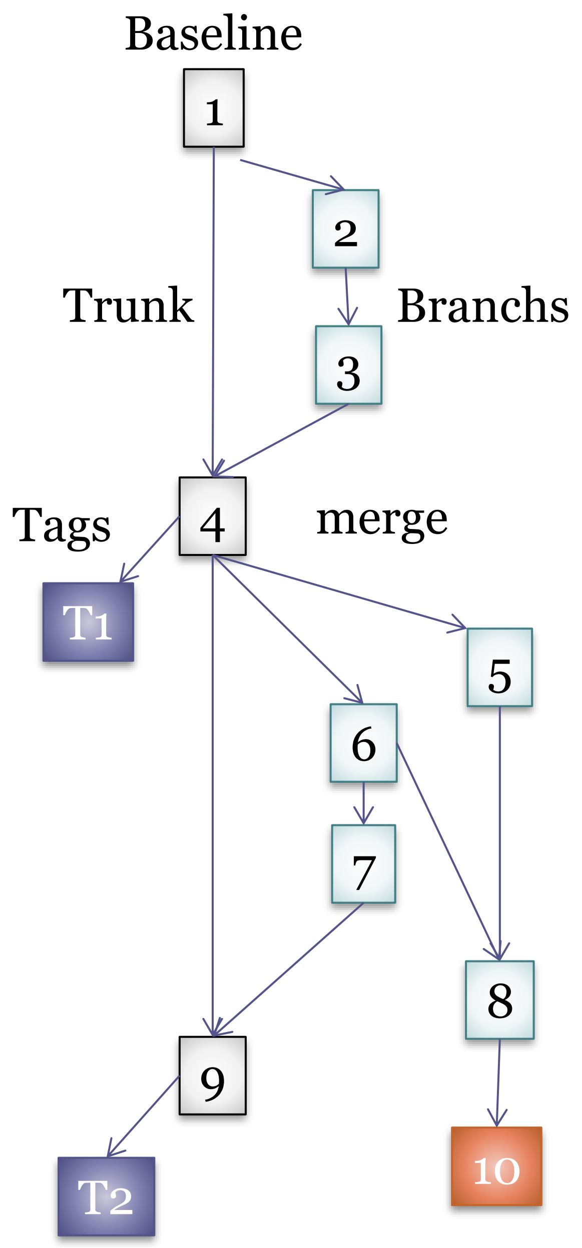
- Static vs dynamic code analysis
  - Without running the code (or at runtime)
  - Examples: PMD, SonarCube,... (Codacy)
- Debuggers
  - Interactive vs static, Tracers & logging
- Profilers
  - Information about resource usage
    - Memory, CPU, method calls, etc.
- Test coverage tools
  - Report which 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

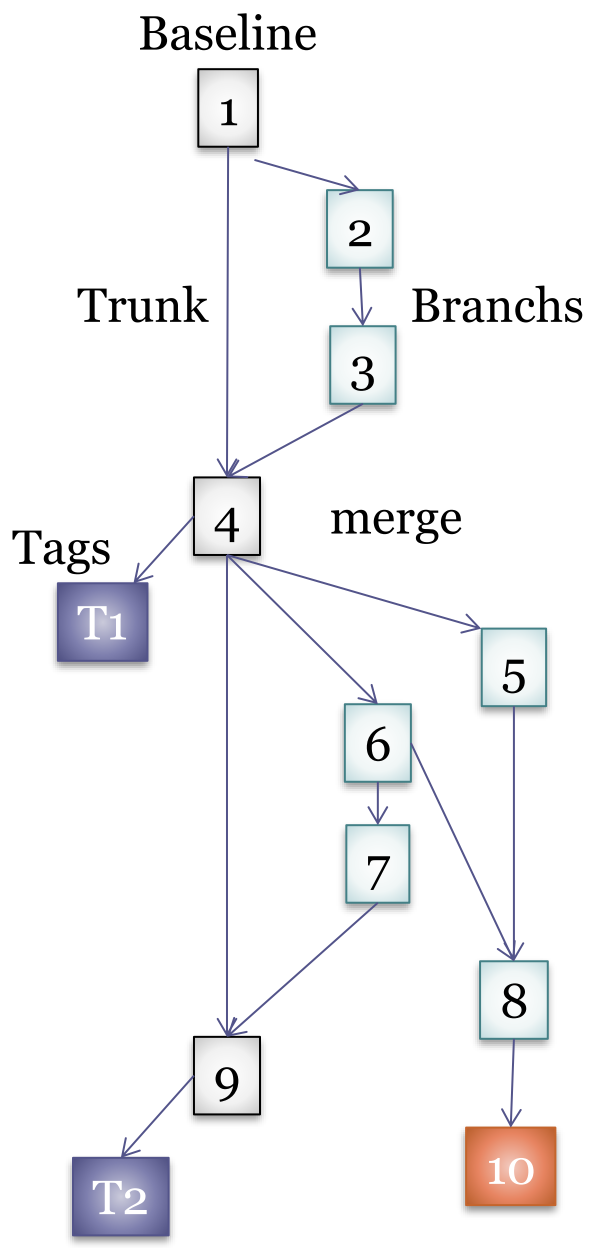
- Repository: where changes are stored
- Baseline: Initial version
- Delta: changes from one version to other
- Trunk (master): Main branch in a system
- Branch: deviation from main branch
- Tag: Marks a line of versions



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:

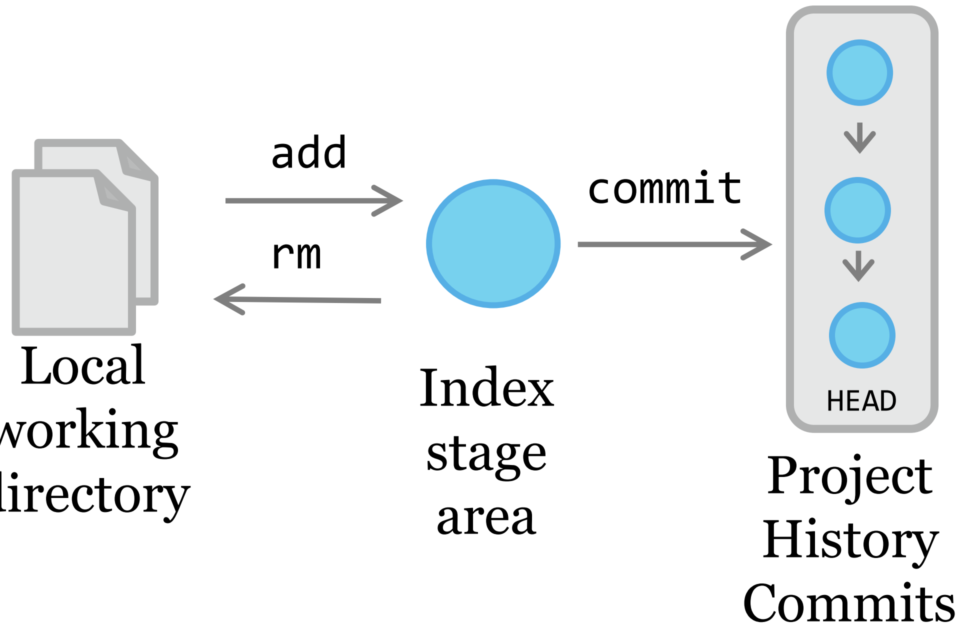
- Applications with large number of source code files
  - Efficiency
- Distributed work
  - Each development has its own repository
    - Local copy of all the changes history
    - It is possible to do commits even without internet connection
- Support for non-lineal development (branching)

More information:
http://rogerdudler.github.com/git-guide/

Local components

3 local components:

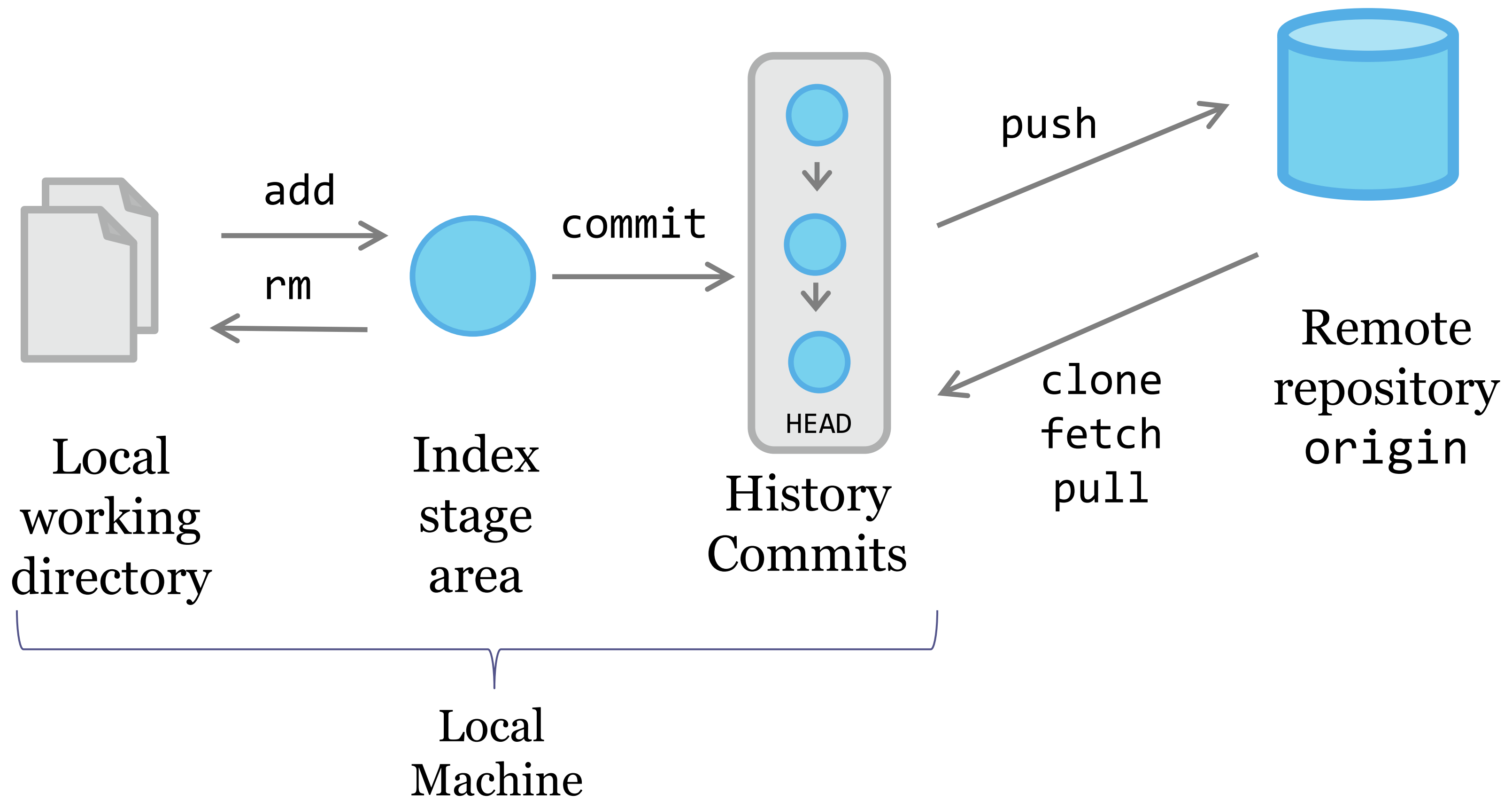
- Local working directory
- Index (stage area). Also called cache
- Project history: Stores versions or commits
  - HEAD (most recent version)



Remote repositories

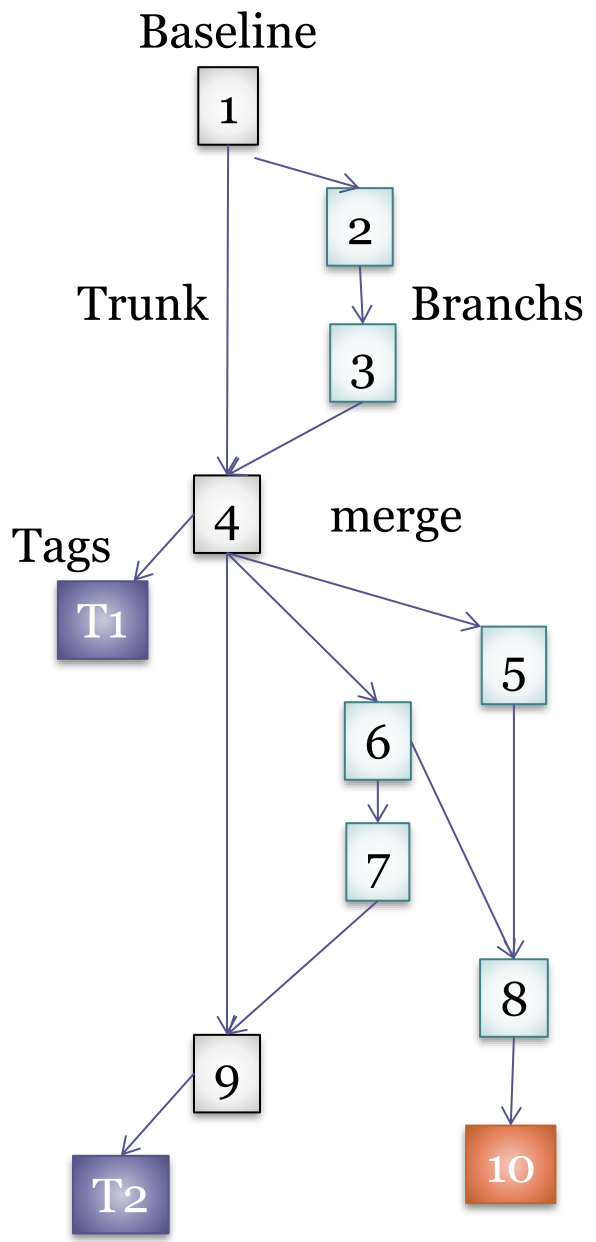
Connect with remote repositories

`origin` = initial



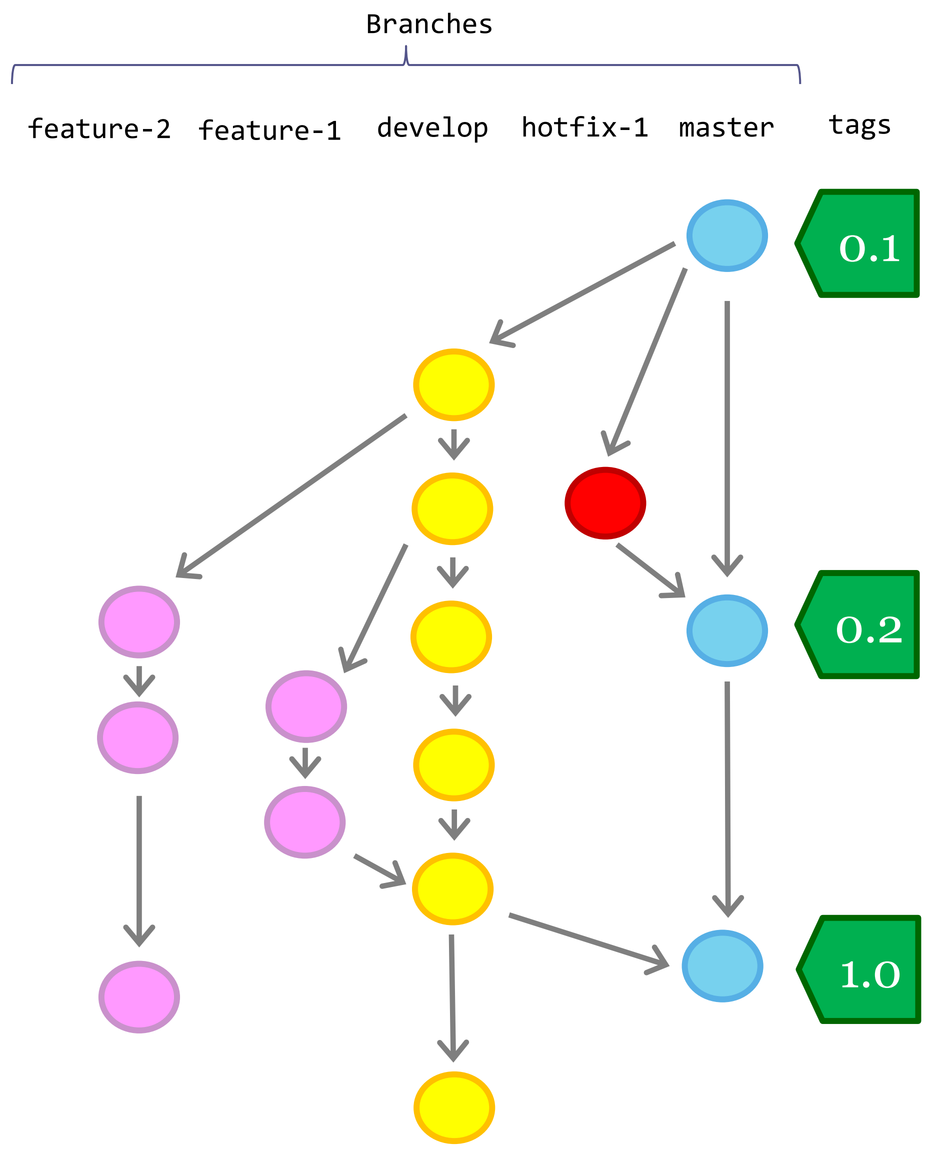
Branches

- 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

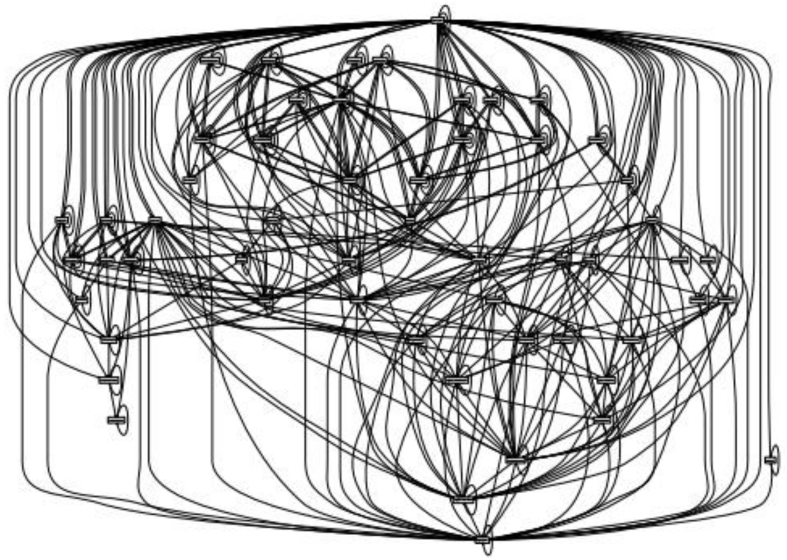


https://martinfowler.com/articles/branching-patterns.html

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



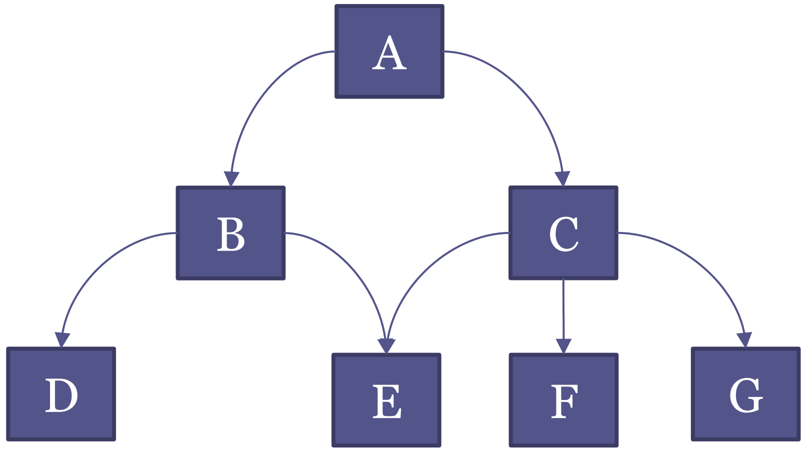
Mozilla Firefox dependency graph
Source: The purely functional deployment model. E. Dolstra (PhdThesis, 2006)

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


$$\begin{tikzcd}
 & & A \arrow[dl, bend right] \arrow[dr, bend left] & & \\
 & B \arrow[dl, bend right] \arrow[dr, bend left] & & C \arrow[dl, bend right] \arrow[d] \arrow[dr, bend left] & \\
D & & E & F & G
\end{tikzcd}$$

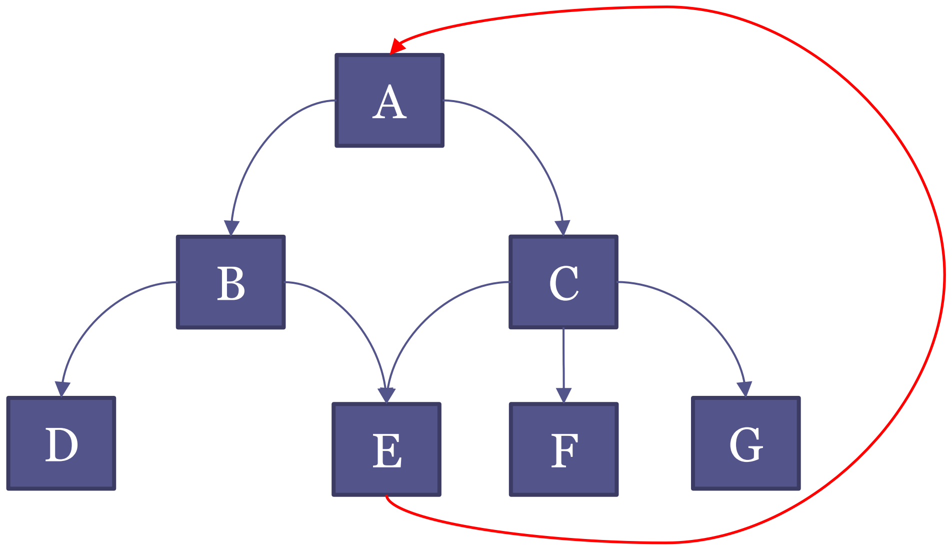
Cyclic dependencies problem

The dependency graph should not have cycles

Adding a cycle can damage CCD

Example:

CCD = 7+7+7+1+7+1+1=31



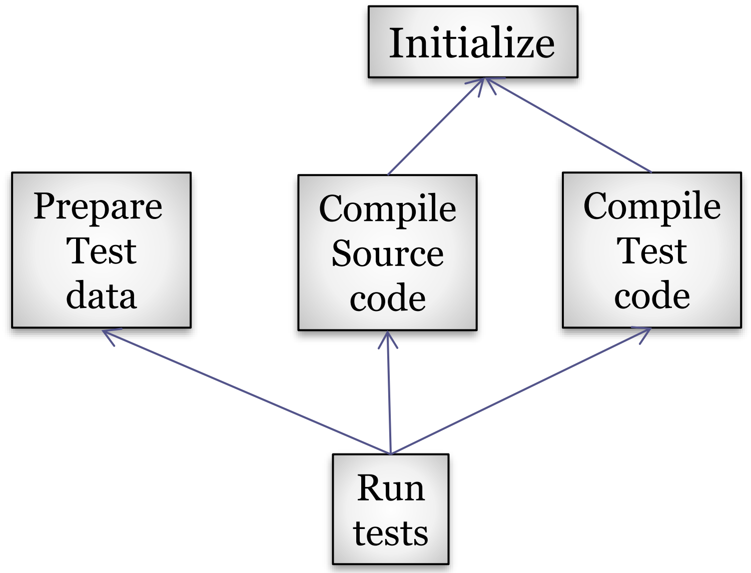
Dependency management

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

Local Artifact Repository
Remote Artifact Repository

`<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>
...
```

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
    - $\Rightarrow$ 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 ≈ node server.js
  - test ≈ 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/