

# Building Large Programs

## (Sestavování velkých aplikací)

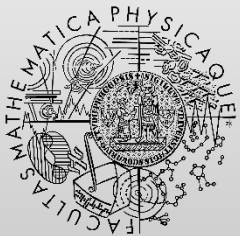
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# Outline

- General introduction
- Specific tools
  - Ant (Java)
  - Maven (Java)
  - MSBuild (C#/.NET)
  - Gradle (Java, Android)
  - CMake (C++)

# Key topics

- Recommended practice and workflow
- Avoiding cyclic dependencies
- How to create modular build scripts

# Ant



- Build tool mostly for Java projects
  - Wide support of tools and frameworks common in the Java world (JUnit, JSP/Servlets, EJB, ...)
- Web: <http://ant.apache.org/>
  - Docs: <http://ant.apache.org/manual/index.html>
- Highly extensible
  - Plug-ins written in Java
- Very portable scripting
- Scripts written in XML
  - Default file name: `build.xml`

# Build file structure

```
<project name="MyProject" default="dist" basedir=". ">
  <property name="src.dir" value="./src"/>
  <property name="build.dir" value="./build"/>

  <target name="init">
    <mkdir dir="${build.dir}"/>
  </target>

  <target name="compile" depends="init">
    <javac srcdir="${src.dir}" destdir="${build.dir}"/>
  </target>

  <target name="clean">
    <delete dir="${build.dir}"/>
  </target>
</project>
```

# Terminology

- Task
  - Specific action to be performed during the build process
    - execute the Java compiler, create new directory
- Target
  - Goal required for building (compilation, packaging, running tests, generating documentation)
  - One phase of the whole process of building your project
  - Set of tasks that must be executed to fulfill the goal
  - May have dependencies on (multiple) other targets
- Project
  - Set of targets relevant for the application
- Property
  - name-value pair (strings)
  - usage: `${prop.name}`

# Basic tasks

- **Compilation of Java source files**

```
<javac srcdir="${src.dir}" destdir="./build"  
      debug="on" deprecation="on"/>
```

- **Running an external Java program**

```
<java classname="myapp.Main" fork="true">  
  <arg value="nswi154"/>  
  <jvmarg value="-Xmx512m"/>  
</java>
```

- **Packaging class files in JAR archive**

```
<jar destfile="myapp.jar" basedir="./build">  
  <manifest>  
    <attribute name="Main-Class" value="..." />  
  </manifest>  
</jar>
```



# Usage

- Typical content of the build script
  - Compilation
    - All source code files written in Java
  - Packaging
    - Creating the JAR archive for distribution
  - Execution of tests
- Good practice
  - Use properties where it makes sense, typical directory layout (`./src`, `./build`), and standard targets (compile, build, init, clean, dist)
  - Specify reasonable dependencies between targets
- Running Ant
  - Command-line: `ant <target name>`

# Dependencies between targets

- Build script

```
<target name="A" />  
<target name="B" depends="A" />  
<target name="C" depends="B" />  
<target name="D" depends="A, C" />  
<target name="E" depends="D, C, A" />
```

- Execution order

**E** → **D, C, A, E**  
**D, C, A, E** → **A, C, D, C, A, E**  
**A, C, D, C, A, E** → **A, B, C, D, C, A, E**  
**A, B, C, D, C, A, E** → **A, A, B, C, D, A, B, C, A, E**  
**A, A, B, C, D, A, B, C, A, E** → **A, B, C, D, E**

# Path-like structures

```
<path id="myapp.classpath">
  <pathelement path="${classpath}"/>
  <fileset dir="lib">
    <include name="**/*.jar"/>
  </fileset>
  <pathelement location="classes"/>
  <dirset dir="${build.dir}">
    <include name="apps/**/classes"/>
    <exclude name="apps/**/*Test*"/>
  </dirset>
  <pathelement location="third_party/util.jar"/>
</path>

<javac ...>
  <classpath refid="myapp.classpath"/>
</javac>
```

This is a modified version of an example from the Apache Ant documentation

# Properties defined externally

- Create the file `build.properties`

```
src.dir=./src
```

```
build.dir=./build
```

```
lib.dir=./lib
```

- ... and include the file in `build.xml`

```
<property file="build.properties"/>
```

# Dependencies between source files

- Recompile everything from scratch
  - We can probably recommend this approach
- Use task <depend>
  - Deletes all obsolete .class files (modified sources)
  - Re-use of some previously compiled class files
  - **Limitation: cannot discover some dependencies**
  - Example

```
<depend srcdir="./src" destdir="${build.dir}"/>
```

# Ant – final remarks

- Examples of build.xml
  - <https://github.com/apache/ant/>
  - <https://github.com/javapathfinder/jpf-core/tree/JPF-8.0>

# Maven



# Maven

- Project management and building tool
  - mainly for Java
- Typical usage scenarios made simpler for users
- Encourages best-practices and conventions
  - Directory layout
  - Naming of tests
- Web: <http://maven.apache.org/>



# Best-practice guidelines

- Directory tree (layout)

```
my-app
|-- pom.xml
|-- src
|   |-- main
|   |   |-- java
|   |   |   |-- com
|   |   |   |   |-- mycompany
|   |   |   |   |   |-- app
|   |   |   |   |   |   |-- App.java
|   |   |-- resources
|   |-- test
|   |   |-- java
|   |   |   |-- com
|   |   |   |   |-- mycompany
|   |   |   |   |   |-- app
|   |   |   |   |   |   |-- AppTest.java
|-- target
|   |-- classes
```

- Test case names

`**/*Test.java, **/Test*.java`

Example taken from <http://maven.apache.org/guides/getting-started/maven-in-five-minutes.html>

# Key concepts

- Goal
  - Single action to be executed
    - Construction of directory layout
    - Compilation of Java sources
  - Similar to **task** in Ant
- Phase
  - Step in the build lifecycle
    - generate-sources, compile, deploy
  - Sequence of goals
  - Similar to **target** in Ant
- Build lifecycle
  - Ordered sequence of phases
  - Similar to **dependencies between targets** in Ant

# Typical build lifecycle

1. validate
2. compile
3. test
4. package
5. integration-test
6. verify
7. install ----- to local repository
8. deploy

# Project Object Model (POM)

- Project's configuration (build script)
  - Stored in the pom.xml file

```
<project>
  <modelVersion>4.0.0</modelVersion>
  <groupId>com.mycompany.app</groupId>
  <artifactId>my-app</artifactId>
  <packaging>jar</packaging>
  <version>1.0-SNAPSHOT</version>
  <name>Maven Quick Start Archetype</name>
  <url>http://maven.apache.org</url>
  <dependencies>
    <dependency>
      <groupId>junit</groupId>
      <artifactId>junit</artifactId>
      <version>4.8.2</version>
      <scope>test</scope>
    </dependency>
  </dependencies>
</project>
```

Example taken from <http://maven.apache.org/guides/getting-started/maven-in-five-minutes.html>

# Usage

- Project setup

```
mvn archetype:generate \  
  -DarchetypeArtifactId=maven-archetype-quickstart \  
  -DgroupId=com.mycompany.app -DartifactId=my-app
```

- Build lifecycle: `mvn <name of a phase>`

- Compilation: `mvn compile`
- Packaging: `mvn package`
- Web-site generation: `mvn site`
- Rebuild into local repository: `mvn clean install`

- Default remote repository (central)

- <https://repo1.maven.org/maven2/>

# Advanced features

- Creating local repositories
- Creating packages with metadata
  - To be stored into repository
- Modifications of standard workflow
- Modules and project inheritance
- Extensibility via plugins
  - Each plugin implements a set of related goals
  - Core: <http://maven.apache.org/plugins/index.html>
  - Mojohaus: <https://www.mojohaus.org/plugins.html>

# Selected plugins

- JAR

- <https://maven.apache.org/plugins/maven-jar-plugin/>

- Clean

- <https://maven.apache.org/plugins/maven-clean-plugin/>

- Exec

- <https://www.mojohaus.org/exec-maven-plugin/>

# Examples

- <http://d3s.mff.cuni.cz/files/teaching/nswi154/maven-ex.tgz>
  - DSI Utilities: original sources, build.xml, **pom.xml**
  - Project home page: <http://dsiutils.di.unimi.it/>
- Maven itself
  - <https://github.com/apache/maven-parent>
    - Shared global declarations
  - <https://github.com/apache/maven> (core)
    - Hierarchy of modules (pom.xml files): api, impl
  - <https://maven.apache.org/scm.html>
  - <https://github.com/apache/maven-sources>



# Want to know more about Maven ?

- Read the guide
  - <http://maven.apache.org/guides/>
- Try it yourself
  - Create new project
  - Add source files
  - Run compilation

# Evaluation: Ant versus Maven

- Ant
  - Very flexible, gives you control over the build
  - Better for small/student projects (less overhead)
- Maven
  - Quite heavy, enforces lot of best practices
  - Good for large SW projects (enterprise-level)
  - Support for modular build scripts is nice
    - Pitfalls: cyclic dependencies between modules

# MSBuild



# MSBuild

- XML syntax of build scripts (“Makefiles”)
  - Used internally by Visual Studio 20xx-22
  - Syntax evolving (non-trivial differences)
  - Familiar concepts: task, target, property
- 
- Homepage
    - <https://learn.microsoft.com/en-us/visualstudio/msbuild/msbuild?view=vs-2022>

# NuGet

- Package manager for .NET
- Similar concepts to Maven
- Integration to Visual Studio
- Web: <https://www.nuget.org/>
- Docs: <https://learn.microsoft.com/en-us/nuget/>

# .NET Core Templates

- Support for project templates
  - Implementing best & recommended practices
- Additional information
  - <https://learn.microsoft.com/en-us/dotnet/core/tools/custom-templates>
  - <https://learn.microsoft.com/en-us/dotnet/core/tools/dotnet-new>
- Template engine
  - <https://github.com/dotnet/templating/>
- Available templates
  - <https://github.com/dotnet/templating/wiki/Available-templates-for-dotnet-new>

# Gradle



- Another popular general-purpose build tool
  - Java, Scala, C, C++, Android
- Encourages best practices (like Maven)
- Script language (DSL) based on Groovy
- Web: <https://gradle.org/>



# Gradle – example build script

- Structure of the script file build.gradle

```
plugins {  
    id 'application' // 'java-library', 'java'  
}  
  
java {  
    toolchain {  
        languageVersion = JavaLanguageVersion.of(11)  
    }  
}  
  
sourceSets { ... }  
dependencies { ... }  
  
// other custom tasks
```

# Gradle – example build script

- Fragments of the build script (configuration)

```
sourceSets {  
    main {  
        java {  
            srcDirs = ['src']  
        }  
    }  
}
```

```
dependencies {  
    implementation files('lib/commons-logging-1.0.3.jar')  
    implementation fileTree(dir: 'lib', include: '**/*.jar')  
}
```

# Gradle – example build script

- Fragments of the build script (actions, custom tasks)

```
tasks.register('initDirs') {
    doLast {
        mkdir "build"
    }
}

tasks.named('clean') {
    delete "build"
}

tasks.register('copyJar', Copy) {
    from layout.buildDirectory.dir("libs/junit.jar")
    into "dist"
}

task copyJarToBin(type: Copy) {
    from 'build/libs/GradleJarProject.jar'
    into "/usr/bin"
}
```

# Gradle – usage

- Running
  - `gradle clean build`
  - `gradle run`
- Project template for Java
  - `gradle init --type java-application`
- Wrapper script: `gradlew.{bat,sh}`
  - Highly recommended to provide for customers
- Additional information
  - [https://docs.gradle.org/current/userguide/tutorial\\_using\\_tasks.html](https://docs.gradle.org/current/userguide/tutorial_using_tasks.html)
  - [https://docs.gradle.org/current/userguide/building\\_java\\_projects.html](https://docs.gradle.org/current/userguide/building_java_projects.html)

# CMake



- Cross-platform free and open-source build management application
- Very popular (usage) for programs in C++
- Compiler-independent tool
  - Supports various native build systems (make, Xcode, MS Visual Studio)
- Web: <https://www.cmake.org/>
- Two phases of the build process
  - Generate native build scripts from platform-independent configuration (CMakeLists.txt)
  - Run target platform's native tool for the actual build

# CMake – build script

```
cmake_minimum_required(VERSION 3.10)
project(myapp)

add_executable(myapp myapp.cpp myapp_gui.cpp)

target_include_directories(myapp include)

add_library(mylib mylib_core.cpp mylib_utils.cpp)
add_subdirectory(mylib)
target_link_libraries(myapp mylib)

find_package(solver REQUIRED)
target_link_libraries(myapp ${Solver_LIBS})
```

# Other build tools

- Ivy
  - <https://ant.apache.org/ivy/>
- Scons
  - <http://www.scons.org/>
- Bazel
  - <http://bazel.io/>
- Cake
  - <https://cakebuild.net/>



# Useful skills

- Experience with build scripts for some tools
  - Creating new scripts from scratch for your own small projects
  - Editing some parts of already existing scripts and configurations
- Recommendations
  - Learn some tools that are new for you (“broaden your horizons”)
  - Ability to modify large scripts is really important