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# Automated software construction

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DCL – build – 2025-2026

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# Important notes

- If you do not understand something, please ask your questions. *We cannot answer the questions you do not ask...*
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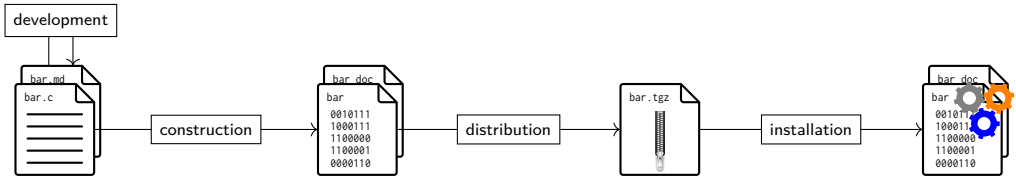
- People don't learn computer science by only reading few academic slides: practicing is fundamental

# Software deployment




- We're looking for automation to deliver better and faster
- Several possible actions
  - compilation, tests, code generation, execution, formating...
  - archive and installer, documentation, release...
  - combinations of several actions

# Different kinds of tools

*System Package Manager*

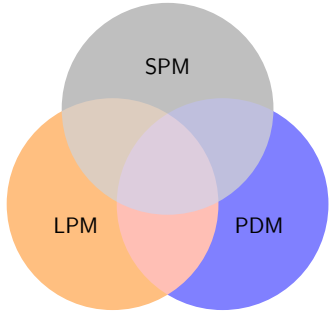
package (parts of application) management (installation, upgrade, ...), often distributed as binaries

ex: `apt`, macos app store, homebrew

*Language Package Manager*

building of language-specific applications and libraries

ex: go tools, npm, opam, cargo, ...

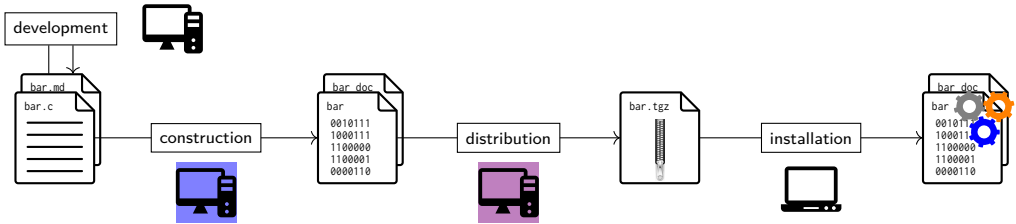



*Project Dependency Manager*

building of a project

ex: maven, gradle, dune, ...

# Different machines




- Several machines are involved, they may have various OS
- The build machine, must be able to build binaries for the user's machine
  - notion of cross-compilation

# Different uses

Production can be

- on demand
  - by invoking the build tool explicitly
  - for instance by the developer, by a package maintainer, ...
- scheduled
  - a server launches a build at a certain frequency : every night, ...
  - for instance, for the regular production of intermediate versions (ex : *nightly versions*)
- triggered
  - construction is launched by an external event
  - for example, build each new `commit` in a certain branch

# The notion of internal dependency

- Complete rebuilding can be costly

⇒ The aim is to minimize unnecessary execution of actions

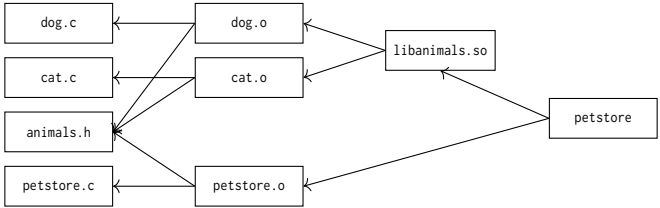
- For each action
  - the inputs must be known
  - the action is re-executed only if one of its inputs has changed
- One must know
  - the dependencies between artifacts (often files), this is called a *dependency graph*
  - the actions that produce these artifacts

⇒ The actions to be performed and their (partial) order can be deduced from this.

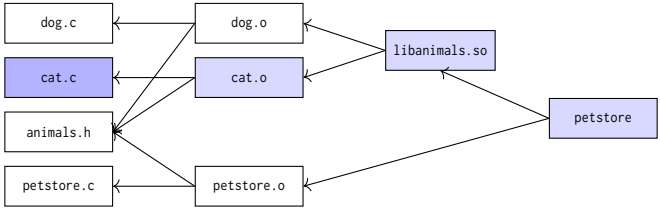
- Generally a dependency graph **without circuit**

Algo: circuit search and topological sorting (DFS-based algorithms)

# An example of a dependency graph

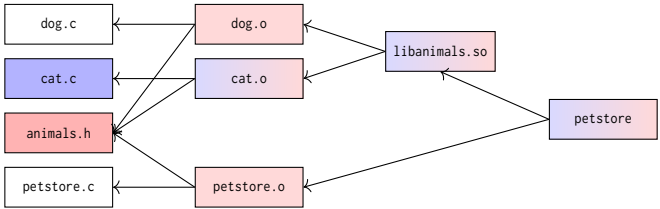


# An example of a dependency graph




- If `cat.c` is modified
- Then one must rebuild `cat.o`, `libanimals.so` and `petstore` in this order

# An example of a dependency graph




- If `cat.c` is modified
- Then one must rebuild `cat.o`, `libanimals.so` and `petstore` in this order
- If `animals.h` is modified
- Then one must rebuild
  - `dog.o`, `cat.o` et `petstore.o` independently
  - then `libanimals.so`
  - and finally `petstore`

# An example of a tool: make

- Is configured with a `Makefile` file

Product

```
dog.o: dog.c animals.h
    gcc -fPIC -c dog.c
```

Depends on

Actions

# An example of a tool: make

- Is configured with a `Makefile` file

Product

```
dog.o: dog.c animals.h          Depends on
    gcc -fPIC -c dog.c          Actions
cat.o: cat.c animals.h
    gcc -fPIC -c cat.c
petstore.o: petstore.c animals.h
    gcc -c petstore.c
libanimals.so:
    gcc -shared -o libanimals.so dog.o cat.o
petstore: animals.so petstore.o
    gcc -o petstore petstore.o -L. -lanimals
```

- Uses file change dates
- Portability of complex actions

# Differents tool categories

- A la `make`
  - action = shell script
- A la `ant`
  - specific action language + Java *framework*

  ⇒ actions are portable but it is a dedicated language
- Build files generation: `automake`, `CMake`

  ⇒ higher level and portable language, reuse of a well-known tool
- Embedded in a script language: `gradle`, `scons`, ...

  ⇒ easier to write tailored and portable actions
- IDE: eclipse, ...

  ⇒ well-integrated for the developer, but a fixed set of actions
- Sometimes, combinations are possible: `gradle`/eclipse

# Expected properties of building tools

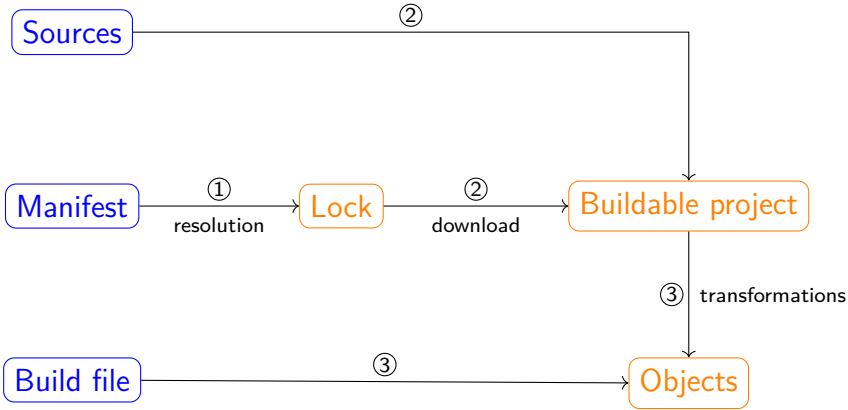
- Correction
  - the artifacts produced must correspond to what is expected
- Efficiency
  - optimal re-execution of actions
  - dependency management is not too costly
- Flexibility
  - the tool can easily produce several versions of artifacts
  - the construction machines can be changed easily
- Reproductibilty (possibly)
  - Identical action executions produce identical artifacts

# Building components

- Project elements (*sources*)
  - source code, resources (images, icons, ...)
- Specification of the external dependencies (*manifest*)
  - other source code, libraries, ...
- Specification of the build tasks (*build file*)
- Exact specification of external dependencies (*lock*)
- The buildable project
  - project elements
  - all dependencies necessary for the build
- The built project (*objects*)

Elements in blue are typically produced by the developer
Elements in orange are typically produced by the build tool
Sometimes, the *manifest* is in the build file

# The build process



# Example

- Sources
  1. Java files, ...
  2. database model
  3. initial database data
  4. test cases
- Objects
  - A generated Java code for DB access
  - B compiled Java classes (`.class` files)
  - C a `jar` archive of Java code
  - D database schema
  - E initialized database
  - F test execution report
- Transformations

$2 \rightarrow$ A,E generation of DB schema & Java code

1,A $\rightarrow$ B Java code compilation

B $\rightarrow$ C production of a code archive

D,3 $\rightarrow$ E DB initialization

C,4,E $\rightarrow$ F test execution and report generation

# Difference between *manifest* and *lock*

- The *manifest*
  - uses a language to define flexible dependencies
  - e.g. Gradle : `'junit:junit:4.+'`
- The *lock*
  - contains the exact dependency choices
  - e.g.: the version `4.12` of JUnit
- Flexible dependencies are necessary to manage transitive dependencies
  - for example, we depend on `A` and we depend on `B`, which depends on `A`
  - if the version of `A` is forced and `B` changes version of `A`
  - there may be a conflict
- The exact version is necessary to be able to reproduce the build

# Packaging

- For distribution to the user, there are several approaches
  - Standard archives: `zip`, `tar.gz`, `jar`, ...
  - SPM : `deb`, `rpm`, ...
  - Graphical installation tools
  - Specific installation tools

# Continuous Integration (CI)

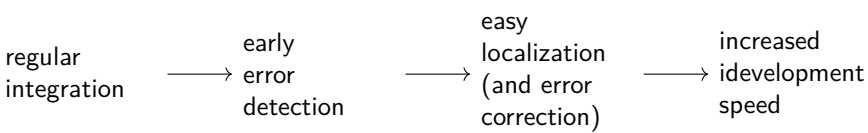
## Definition

Development practice that frequently integrates developers' work into a shared repository and that ensures the repository is in a workable state.

- Each integration triggers build and verification tasks
- Several iterative and incremental integrations *vs* a final integration

$\Rightarrow$ early detection of problems

$\Rightarrow$ improves quality



# Continuous *

- integration : version management + automated build and testing
- delivery : continuous integration continue + delivery (*releases*)
- deployment : continuous delivery with automated deployment

# CI toolset requirements

CI requirements

- sharing code and other artefacts
- integrating often
- testing integration
- communicating build results

Needed tools

- control version systems (Git, Subversion, ...)
- test frameworks (JUnit, ...), analysers (PMD, ...)
- build systems (Make, Ant, Gradle, ...)
- dashboard, emails, RSS feeds or chat systems with notifications, bug reports, ...

# CI systems: *one tool to unite them all*

- aggregate other tools
- run the integration processes
- distribute the integration tasks to workers
- present build results


# CI IRL

Demo: Jenkins or Gitlab-ci (if time permits)

# Some references

- https://en.wikipedia.org/wiki/List_of_build_automation_software
- https://medium.com/@sdboyer/so-you-want-to-write-a-package-manager-4ae9c17d9527
- https://media.ccc.de/v/camp2015-6657-how_to_make_your_software_build_reproducibly

# Gentle reminder

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