Building Software

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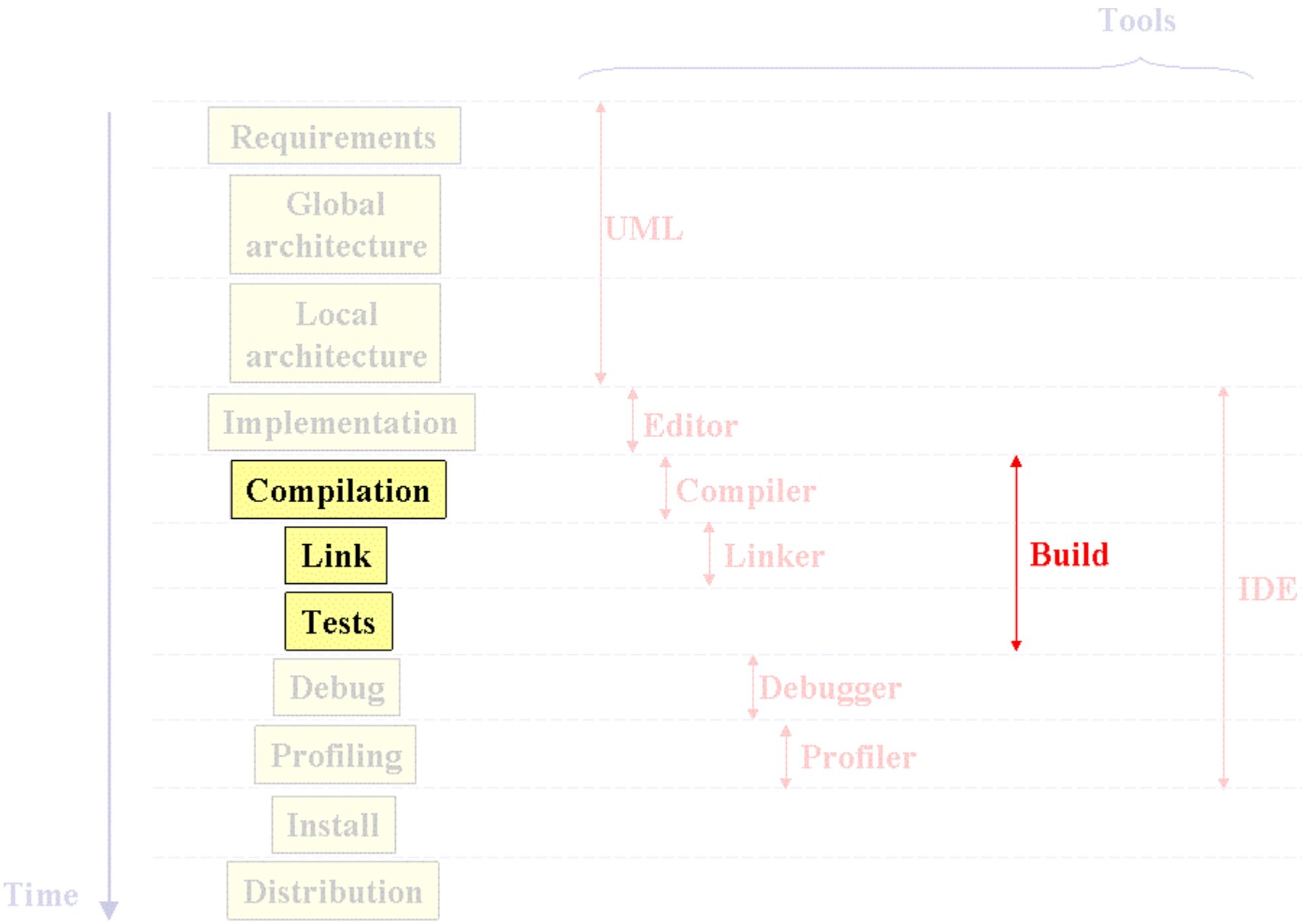
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Outline

- Understand the compilation workflow
- What is painful about it ?
- How can we automate it ?

Compilation

Typical compiled languages (C,C+,Java) require lots of intermediate steps before execution:

- Preprocessing
- Parsing
- Code generation
- Object file generation
- Linking
- Loading

Basic Definitions

- *Source and header text files* : foo.h, bar.cc
- *Object file* : binary file which contains the compiled version of a source file.
- *Library* : a collection of object files stored in a single binary file. Used to package independent “components”.
- *Executable* : a single binary file which can be loaded and executed on a system
- *Process* : a version of an executable running on a given system

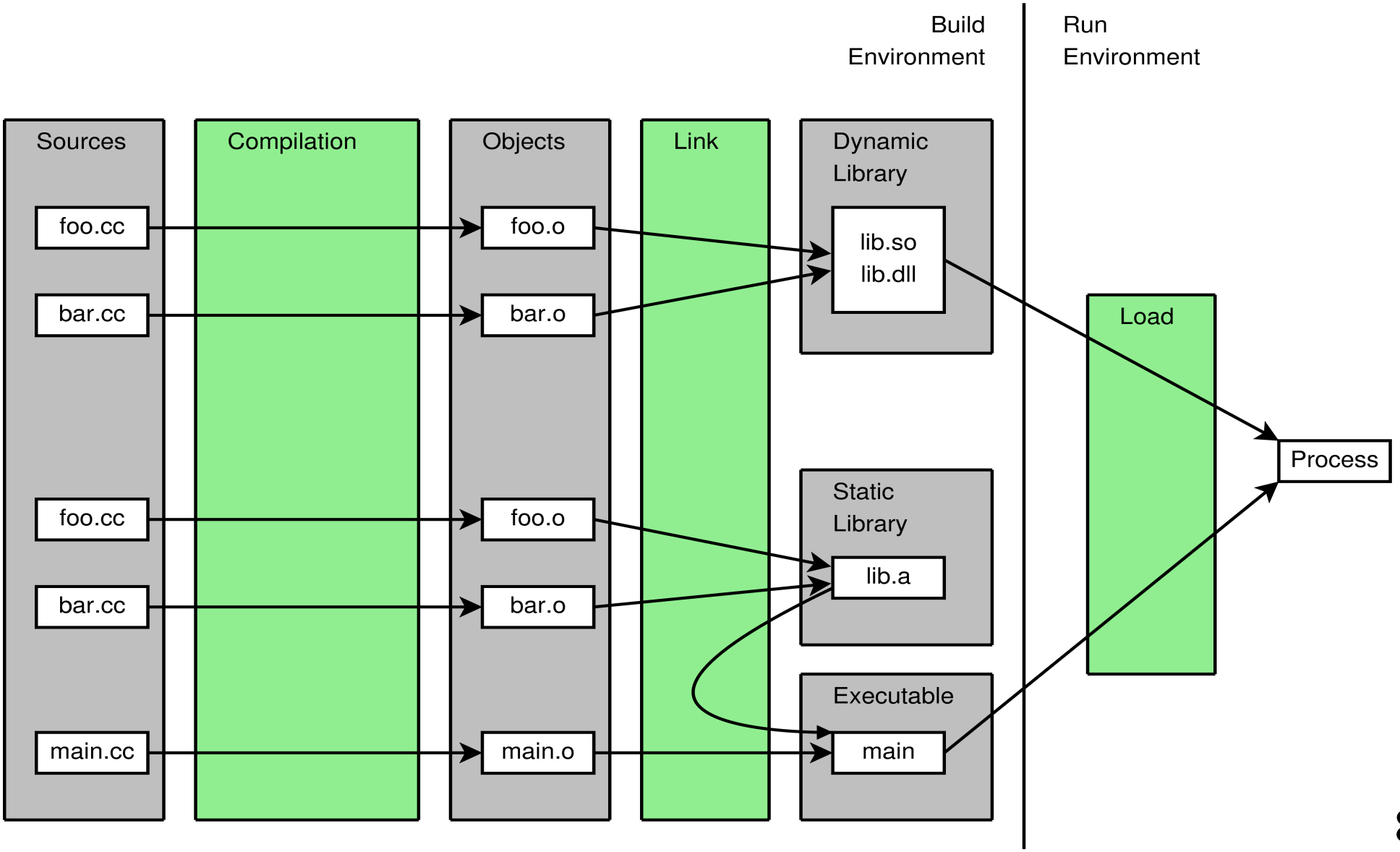
Tool Definitions

- *Compiler* : the tool used to generate an object file from a source file.
- *Linker* : the tool used to generate an executable or a library from a set of object files.
- *Loader* : the tool used to create a working Process from an executable and a set of dynamic libraries.

Library Definitions

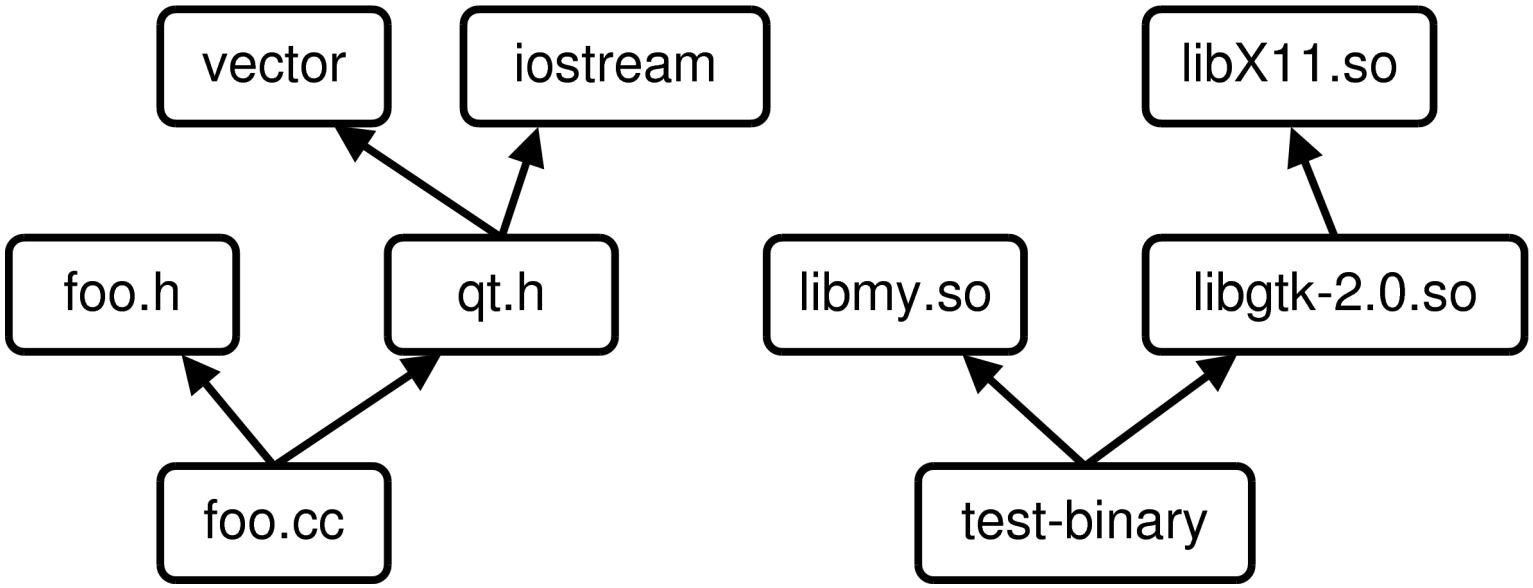
- Executable X uses library Y
- *Static library* :
  - During executable link : copy the object files needed into the final executable.
  - Ignored during executable loading.
- *Dynamic library* :
  - During executable link : record a dependency into the final executable.
  - During executable load : lookup the dynamic library and load it in memory before starting execution

Build overview



Dependency tracking

- What is a dependency ?
  - foo.cc includes foo.h and qt.h
  - bar.java uses package com.sun.something
  - libgtk-2.0.so depends on libX11.so
  - test-binary depends on libmy.so and libgtk-2.0.so



What is hard about a build ?

- Speed: do not rebuild everything when you change one small file
- Dependencies : ensure a correct build
- Using libraries correctly and efficiently : this is very low-level and platform-specific.

A real-life example

- A moderate-sized project, ns-3 :
  - All builds are correct
  - All builds are repeatable
  - Very accurate dependency tracking
  - Build is automatic
- Uses Scons but every other build tool works the same way.

```
[mathieu@mathieu ns-3-dev]$ scons
scons: Reading SConscript files ...
scons: done reading SConscript files.
scons: Building targets ...
g++ -g3 -Wall -Werror -fPIC -DRUN_SELF_TESTS
-DNS3_DEBUG_ENABLE -DNS3_ASSERT_ENABLE -Ibuild-dir/dbg-
shared/include -c -o build-dir/dbg-
shared/src/simulator/high-precision-128.o
src/simulator/high-precision-128.cc
...
```

A simple example

- Platform : Linux
- Tools :
  - Gcc
  - GNU make
- Files : main.cc, a.cc, a.h, ... c.cc, c.h
- a.cc includes a.h and c.h
- b.cc includes b.h
- c.cc includes c.h
- main.cc includes a.h, b.h and c.h
- If a header changes, only the files which include it should be recompiled

Make Principles

- *Target* : a file to generate
- *Prerequisite* : a file which is needed to generate a target
- *Command* : a command to run to create a target once all the prerequisites are available
- Syntax : target is built by command from prerequisites req1, req2, req3, and req4. [tab] is a real ascii tab character:

```
target: req1 req2 req3 req4
[tab]command
```

Make on our example

```
# a.o is generated from a.cc. a.o depends on a.h, c.h
a.o: a.cc a.h c.h
b.o: b.cc b.h
c.o: c.cc c.h
main.o: main.cc a.h b.h c.h
# main executable depends on main.o, a.o, b.o, and c.o
main: main.o a.o b.o c.o
```

- Makefile describes a dependency tree among object files.
- By default, make knows how to “build” every file based on its extension.
- Make keeps track of up-to-date files with file timestamps

Running our example

```
[mlacage@garfield seminar-build]$ make main
g++    -c -o main.o main.cc
g++    -c -o a.o a.cc
g++    -c -o b.o b.cc
g++    -c -o c.o c.cc
cc   main.o a.o b.o c.o   -o main
[mlacage@garfield seminar-build]$ touch c.h
[mlacage@garfield seminar-build]$ make main
g++    -c -o main.o main.cc
g++    -c -o a.o a.cc
g++    -c -o c.o c.cc
cc   main.o a.o b.o c.o   -o main
[mlacage@garfield seminar-build]$
```

A small bug

- In the previous example, we can see a small bug: make links our c++ program with the 'cc' command rather than the 'g++' command. Easy to fix:

```
main: main.o a.o b.o c.o
        g++ -o $@ $^
```

- We override the default rule with our own: '$@' and '$^' are two variables which identify the name of the target and the list of prerequisites respectively.

Other Build Tools

- Choice depends on :
  - Operating Systems targeted
  - Programming Language used
  - Libraries used?
  - ...
- For example :
  - *Autotools*
  - *Ant*
  - *Cmake*
  - *Scons*
  - *...*

Build tool summary

	Languages	Platforms	Documentation	Learning curve
Make	All	All	Good	Average
Automake Autoconf Libtool	C,C++	Unix, cygwin	Good	Bad
Cmake	C,C++	Unix, win32	Good	Good
Qmake	C,C++	Unix, win32, osx	Good	Good
Ant	Java	All	Good	Good
Scons	C,C++	Unix, win32, cygwin, osx	Good	Good

Conclusions

- If you use libraries, you must learn how they work on your platform:
  - On linux, http://www-sop.inria.fr/dream/intro-devel-env.html
  - “Linkers and Loaders” by John Levine, http://www.iecc.com/linker/

- For small projects, using GNU make is very easy:
  - http://www.gnu.org/software/make/manual/
  - “Managing projects with GNU Make”, by Robert Mecklenburg