Modern C++ for Computer Vision and Image Processing

Igor Bogoslavskyi and Cyrill Stachniss

UNIVERSITÄT BONN

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Outline

Course introduction

Linux introduction

C++ syntax

- Hello World!

What you will learn in course

- How to work in Linux
- How to write software with modern `C++`
- Core software development techniques
- How to work with images using `OpenCV`
- How to implement **inverse image search**

Check out **Google Image Search** for example: https://images.google.com/

Why C++? Why Linux? Why?

stackoverflow

Developer Survey Results

2018

- Over 50 000 developers surveyed
- Nearly half of them use Linux
- C++ is the most used systems language (4.5 million users in 2015)
- C++11 is a modern language
- All companies want C++ in our field

Stack Overflow survey: `https://insights.stackoverflow.com/survey/2018/`

CLion survey: `https://blog.jetbrains.com/clion/2015/07/infographics-cpp-facts-before-clion/`

Course structure

The course is split in **two parts**:

1. **Learning the basics**
   - Consists of lectures and homeworks
   - 5 homeworks, 10 points each
   - 25 points moves you to the next part
2. **Working on a project**
   - Plan and code **inverse image search**
   - Groups of 2 — 3 people
   - Final project presentation in the end of semester
   - **Exam = project presentation**

Batteries included!

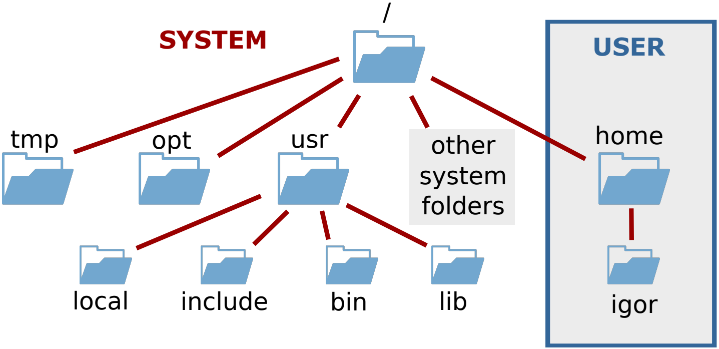
We will provide you with all the essential tools for the course:

- An **Ubuntu virtual machine**
- Lecture recordings on ECampus, YouTube
- Git server to store your code and submit homework assignments

What is Linux?

- Linux is a free **Unix-like OS**
- Linux kernel implemented by Linus Torvalds
- **Extremely popular:** Android, ChromeOS, servers, supercomputers, etc.
- Many **Linux distributions** available
- Use any distribution if you have preference
- Examples will be given in **Ubuntu**

Linux directory tree



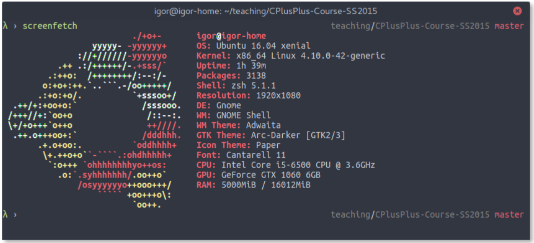
- Tree organization starting with root: `/`
- There are no volume letters, e.g. `C:`, `D:`
- User can only access his/her own folder

Understanding files and folders

- Folders end with `/` e.g. `/path/folder/`
- Everything else is files, e.g. `/path/file`
- Absolute paths start with `/`
  while all other paths are relative:
  - `/home/igor/folder/` — **absolute** path to a folder
  - `/home/igor/file.cpp` — **absolute** path to a file
  - `folder/file` — **relative** path to a file
- Paths are case sensitive:
  `filename` is different from `FileName`
- Extension is part of a name:
  `filename.cpp` is different from `filename.png`

Linux terminal

- Press Ctrl + Alt + T to open terminal



igor@igor-home: ~/teaching/CPlusPlus-Course-SS2015

~~~
λ › screenfetch                                                   teaching/CPlusPlus-Course-SS2015 master
                          ./+o+-       igor@igor-home
                  yyyyy- -yyyyyy+      OS: Ubuntu 16.04 xenial
               ://+//////-yyyyyyo      Kernel: x86_64 Linux 4.10.0-42-generic
           .++ .:/++++++/-.+sss/`      Uptime: 1h 39m
         .:++o:  /++++++++/:--:/-      Packages: 3138
        o:+o+:++.`..```.-/oo+++++/     Shell: zsh 5.1.1
       .:+o:+o/.          `+sssoo+/    Resolution: 1920x1080
  .++/+:+oo+o:`             /sssooo.   DE: Gnome
 /+++//+:`oo+o               /::--:.   WM: GNOME Shell
 \+/+o+++`o++o               ++////.   WM Theme: Adwaita
  .++.o+++oo+:`             /dddhhh.   GTK Theme: Arc-Darker [GTK2/3]
       .+.o+oo:.          `oddhhhh+    Icon Theme: Paper
        \+.++o+o``-````.:ohdhhhhh+     Font: Cantarell 11
         `:o+++ `ohhhhhhhhyo++os:      CPU: Intel Core i5-6500 CPU @ 3.6GHz
           .o:`.syhhhhhhh/.oo++o`      GPU: GeForce GTX 1060 6GB
               /osyyyyyyo++ooo+++/     RAM: 5000MiB / 16012MiB
                   `````` +oo+++o\:
                          `oo++.
λ ›                                                               teaching/CPlusPlus-Course-SS2015 master
~~~

- Linux terminal is a very powerful tool
- Most tasks can be done faster from the terminal than from the GUI

Navigating tree from terminal

- Terminal is always in some folder
- `pwd`: **p**rint **w**orking **d**irectory
- `cd <dir>`: **c**hange **d**irectory to `<dir>`
- `ls <dir>`: **l**i**s**t contents of a directory
- Special folders:
  - `/` — root folder
  - `~` — home folder
  - `.` — current folder
  - `..` — parent folder

Structure of Linux commands

Typical structure

```
${PATH}/command [ options ] [ parameters ]
```

- `${PATH}/command`: obsolute or relative path to the program binary
- `[options]`: program-specific options e.g. `-h`, or `--help`
- `[parameters]`: program-specific parameters e.g. input files, etc.

Use help with Linux programs

- `man <command>` — **man**ual
  exhaustive manual on program usage
- `command -h`
  `command --help`
  usually shorter help message

```
igor@igor-lab:~$ pdfpc -h
pdfpc v3.1.1
Usage:
  pdfpc [OPTION...] <pdf-file>
Help Options:
  -h, --help            Show help options
Application Options:
  -d, --duration=N      Duration in minutes
<...etc...>
```

Using command completion

Pressing ↹ while typing:

- completes name of a file, folder or program
- “beeps” if current text does not match any file or folder uniquely

Pressing ↹+↹ shows all potential matches

Example:

```
igor@igor-work:~> cd te [TAB] [TAB]
teaching/ temp/ testing/
```

Creating and manipulating files and folders

- `mkdir [-p] <foldername>` — **make** **dir**ectory
  Create a folder `<foldername>`
  (with all parent folders `[-p]`)
- `rm [-r] <name>` — **rem**ove [recursive]
  Remove file or folder `<name>`
  (With folder contents `[-r]`)
- `cp [-r] <source> <dest>` — **cop**y
  Copy file or folder from `<source>` to `<dest>`
- `mv <source> <dest>` — **move**
  Move file or folder from `<source>` to `<dest>`

Using placeholders

Placeholder	Meaning
`*`	Any set of characters
`?`	Any single character
`[a-f]`	Characters in `[abcdef]`
`[^a-c]`	Any character **not** in `[abc]`

Can be used with most of terminal commands: `ls`, `rm`, `mv` etc.

Example: placeholders

```
igor@igor-laptop:~/teaching/demo> ls
u01.tex  u02.tex  u03.tex  v01_a.tex  v01.pdf  v01.tex
    v02.pdf  v02.tex  v03.pdf  v03.tex
igor@igor-laptop:~/teaching/demo> ls *.pdf
v01.pdf  v02.pdf  v03.pdf
igor@igor-laptop:~/teaching/demo> ls u*
u01.tex  u02.tex  u03.tex
igor@igor-laptop:~/teaching/demo> ls ?01*
u01.tex  v01_a.tex  v01.pdf  v01.tex
igor@igor-laptop:~/teaching/demo> ls [uv]01*
u01.tex  v01_a.tex  v01.pdf  v01.tex
igor@igor-laptop:~/teaching/demo> ls u0[^12].tex
u03.tex
```

Standard input/output channels

- Single input channel: `stdin`
- Two output channels:
  - `stdout`: Standard output: channel 1
  - `stderr`: Standard **err**or output: channel 2
- Redirecting `stdout`
  - `command 1> out.txt`
  - `command >> out.txt`
- Redirecting `stderr`
  - `command 2> out.txt`
- Redirect `stdout` and `stderr` into a file
  - `progamm > out.txt 2>&1`
- Write `stdout` and `stderr` into different files
  - `progamm 1>stdout.txt 2>stderr.txt`

Working with files

- `more/less/cat <filename>`
  Print the contents of the file
  Most of the time using `cat` if enough
- `find <in-folder> -name <filename>`
  Search for file `<filename>` in folder `<in-folder>`, allows wildcards
- `grep <what> <where>`
  Search for a string `<what>` in a file `<where>`

Chaining commands

- `command1; command2; command3`
  Calls commands one after another
- `command1 && command2 && command3`
  Same as above but fails if any of the commands returns a non-zero code
- `command1 | command2 | command3`
  Pipe `stdout` of `command1` to `stdin` of `command2` and `stdout` of `command2` to `stdin` of `command3`
- Piping commonly used with `grep`:
  `ls | grep smth` look for `smth` in output of `ls`

Canceling commands

- `CTRL + C`
  Cancel currently running command
- `kill -9 <pid>`
  Kill the process with id `pid`
- `killall <pname>`
  Kill all processes with name `pname`
- `htop (top)`
  - Shows an overview of running processes
  - Allows to kill processes by pressing F9

Command history

The shell saves the history of commands in the `~/.bash_history` file

- ↑: go to the previous command
- ↓: go to the next command
- Ctrl + R <query>: search in history
- `less .bash_history`: show history

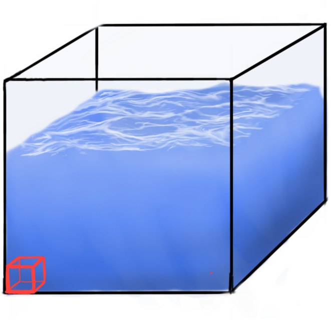
Installing software

Most of the software is available in the system repository. To install a program in Ubuntu type this into terminal:

- `sudo apt update` to update information about available packages
- `sudo apt install <program>` to install the program that you want
- Use `apt search <program>` to find all packages that provide `<program>`
- Same for any library, just with `lib` prefix

Icon taken from Wikipedia

We won’t teach you everything about C++



> Within C++, there is a much smaller and cleaner language struggling to get out.

-Bjarne Stroustrup

Where to write C++ code

There are two options here:

- Use a C++ **IDE**
  - CLion
  - Qt Creator
  - Eclipse
- Use a **modern text editor** `[recommended]`
  - Sublime Text 3 `[my preference]`
  - Visual Studio Code
  - Atom
  - VIM `[steep learning curve]`
  - Emacs `[steep learning curve]`

Most icons are from Paper Icon Set: `https://snwh.org/paper`

Hello World!

Simple C++ program that prints `Hello World!`

```cpp
#include <iostream>

int main() {
  // Is this your first C++ program?
  std::cout << "Hello World!" << std::endl;
  return 0;
}
```

Comments and any whitespace chars are completely ignored

- A comment is text:
  - On one line that follows //
  - Between /* and */
- All of these are valid C++:

```cpp
int main() {return 0;}  // Unexpected comment.
```

```cpp
int main()

{         return 0;
}
```

```cpp
int main() {
  return /* Unexpected comment */ 0;
}
```

Good code style is important

> Programs are meant to be read by humans and only incidentally for computers to execute.
>
> -Donald Knuth

- Use `clang_format` to format your code
- use `cpplint` to check the style
- Following a style guide will save you time and make the code more readable
- We use **Google Code Style Sheet**
- Naming and style recommendations will be marked by `GOOGLE-STYLE` tag in slides

Google style sheet: https://google.github.io/styleguide/cppguide.html

Everything starts with main

- **Every** C++ program starts with `main`
- `main` is a function that returns an error code
- Error code `0` means `OK`
- Error code can be any number in `[1, 255]`

```cpp
int main() {
  return 0;  // Program finished without errors.
}
```

```cpp
int main() {
  return 1;  // Program finished with error code 1.
}
```

#include directive

Two variants:

- `#include <file>` — system include files
- `#include "file"` — local include files

Copies the content of `file` into the current file

```
#include "some_file.h"
// We can use contents of file "some_file.h" now.
int main() {
  return 0;
}
```

I/O streams for simple input and output

- Handle `stdin`, `stdout` and `stderr`:
  - `std::cin` — maps to `stdin`
  - `std::cout` — maps to `stdout`
  - `std::cerr` — maps to `stderr`
- `#include <iostream>` to use I/O streams
- Part of C++ standard library

```
#include <iostream>
int main() {
  int some_number;
  std::cin >> some_number;
  std::cout << "number = " << some_number << std::endl;
  std::cerr << "boring error message" << std::endl;
  return 0;
}
```

Compile and run Hello World!

- We understand **text**
- Computer understands **machine code**
- **Compilation** is translation from text to machine code
- **Compilers** we can use on Linux:
  - GCC
  - Clang [*] [used in examples]

Compile and **run** Hello World example:

```
c++ -std=c++11 -o hello_world hello_world.cpp
./hello_world
```

References

- **Cpp Core Guidelines:** https://github.com/isocpp/CppCoreGuidelines
- **Google Code Styleguide:** https://google.github.io/styleguide/cppguide.html
- **Git guide:** http://rogerdudler.github.io/git-guide/
- **C++ Tutorial:** http://www.cplusplus.com/doc/tutorial/
- Book: **Code Complete 2** by Steve McConnell