Programming for today's physicists and engineers

D. Rabady, CERN

ISOTDAQ 2024: 14th International School of Trigger and Data Acquisition
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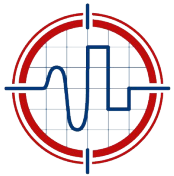


ISOTDAQ
International School of Trigger and Data Acquisition

Opening words

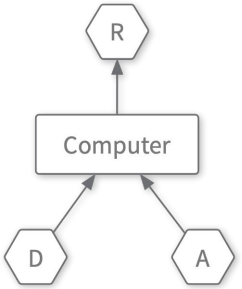
Disclaimer: This is more a collection of pointers* than a tutorial, it's a starting point…
(Almost) no code but a bias towards C++ and Python

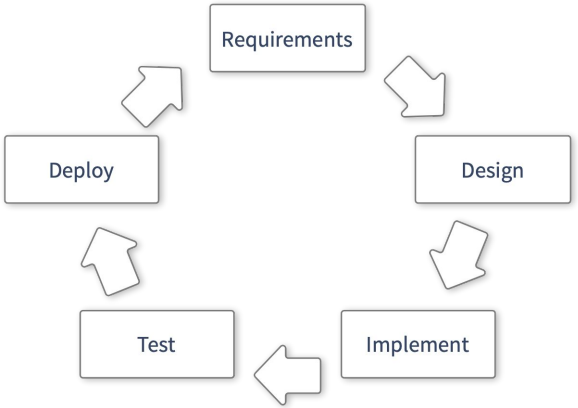
Note: While the lecture focus is software, most of the content equally applies to firmware programming.

Acknowledgment: Slides are based on previous lectures by Alessandro Thea, Joschka Pöttgen (Lingemann) and Erkcan Ozcan

*further reading and tips in these boxes

What is programming?





https://en.m.wikipedia.org/wiki/Systems_development_life_cycle

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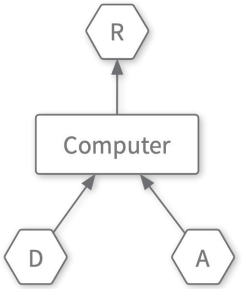
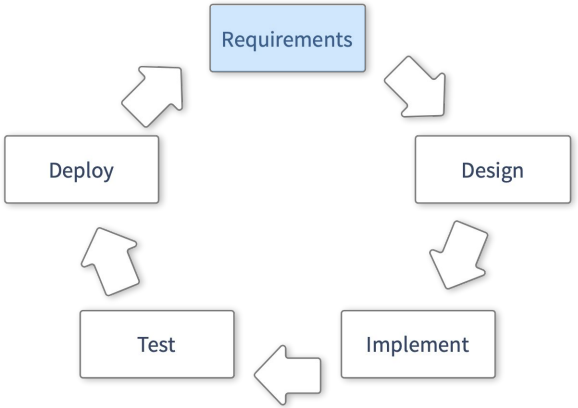
  - Define the requirements for your software
  - Choose the language





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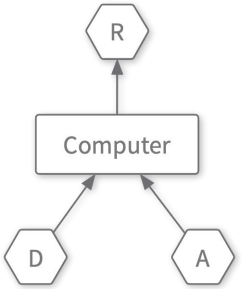
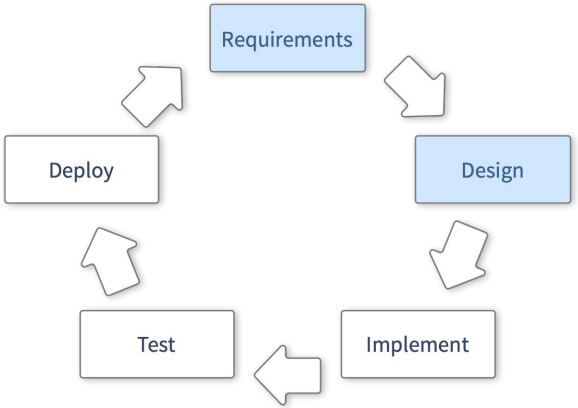
- Formulate a possible solution (design)
  - Identify key functionalities and features





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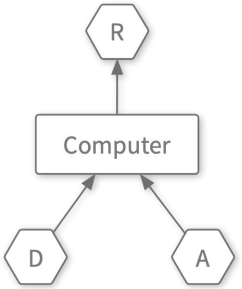
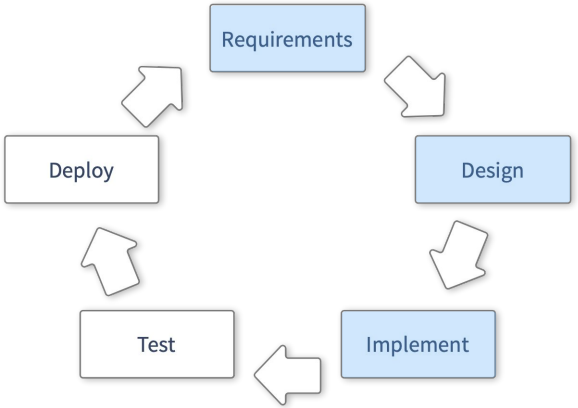
  - Prepare documentation





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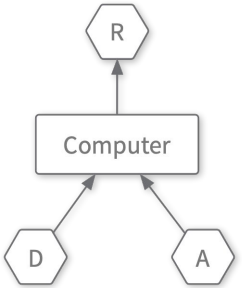
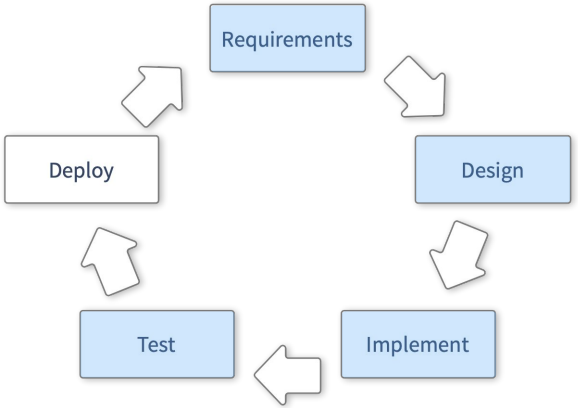
  - Execute unit and system tests





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- Validate the code
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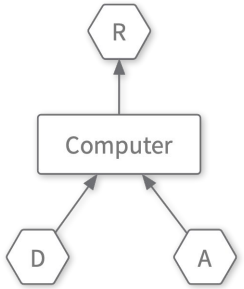
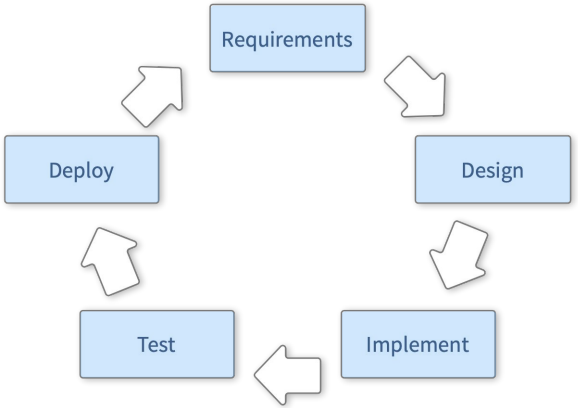
  - Execute unit and system tests
- Deliver the code
  - Collect feedback
  - Ensure portability to different platforms?
- Go back to square 1





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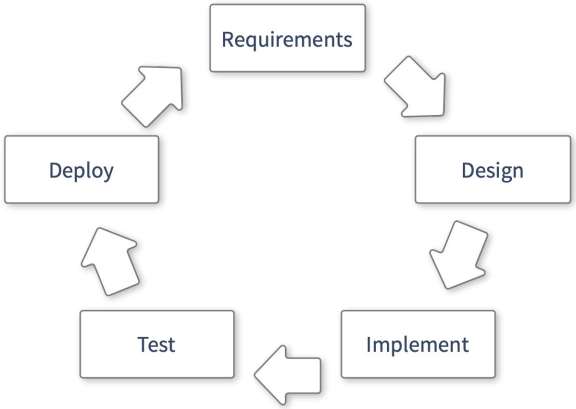
What can programming be like...



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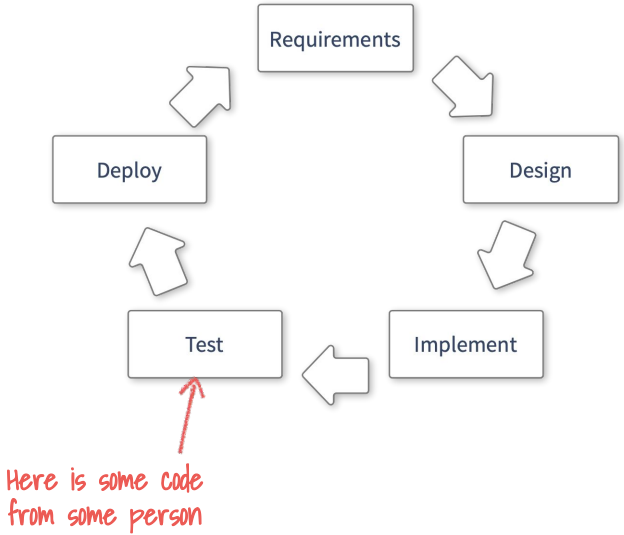

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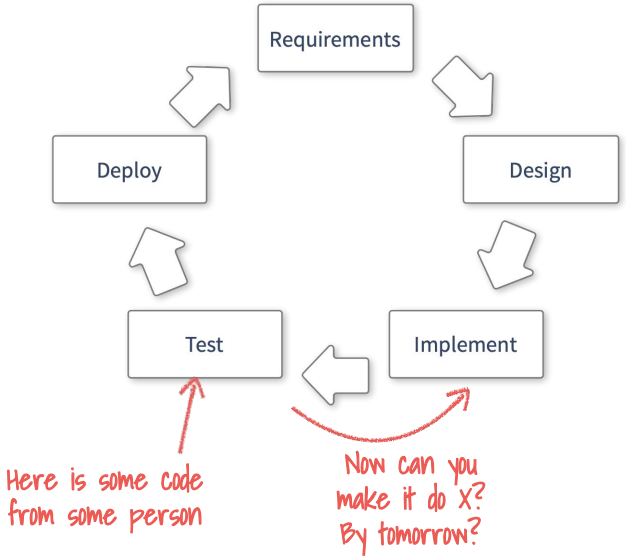

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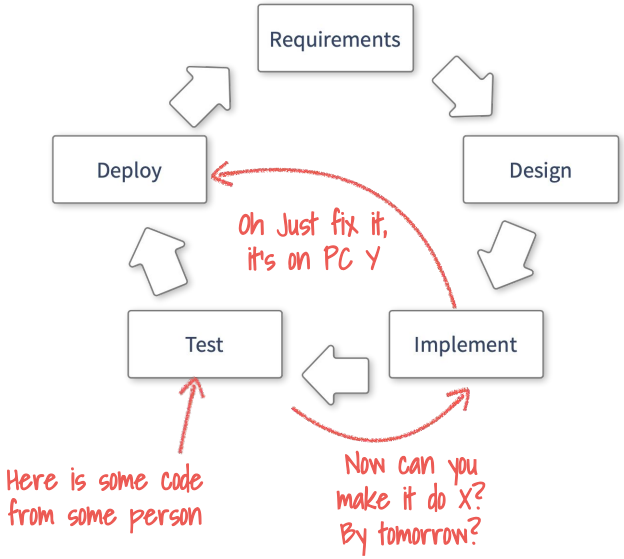
  - Well, it's the only place where the code runs, isn't it?



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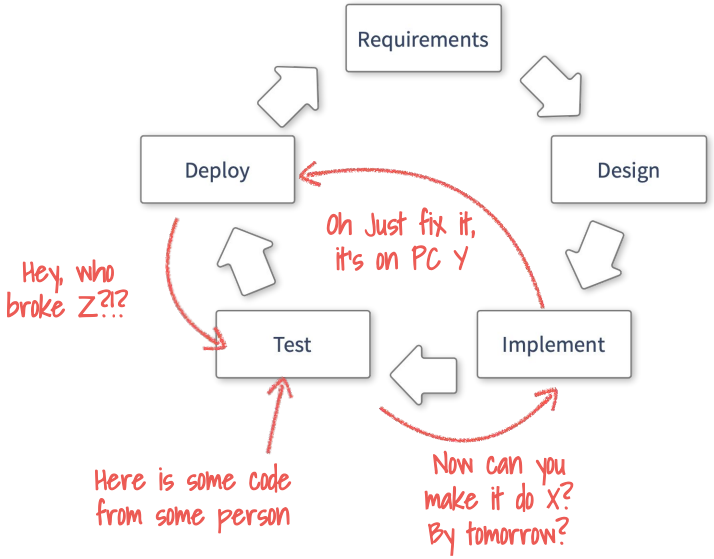
- Break some other code by accident
  - Desperately try to figure out why.



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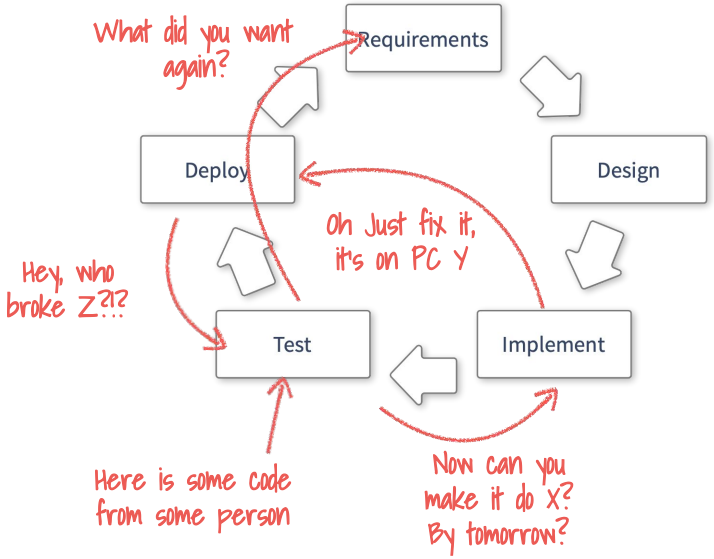

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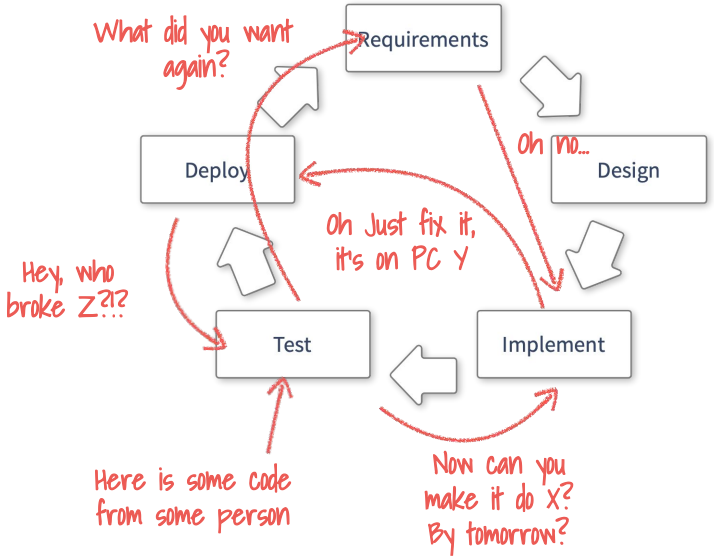
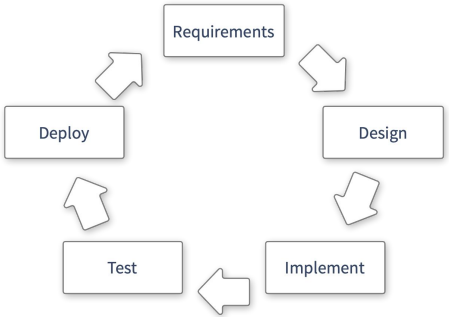
- Just to finally realise you got it wrong in the first place...
  - And so on and so on...



But it doesn't have to be...

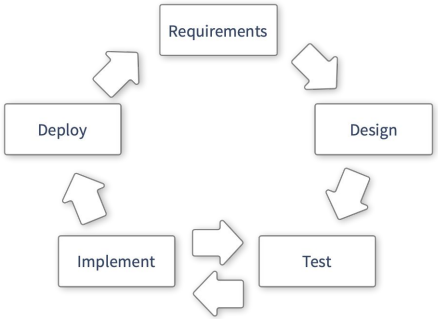
- Many ways to do this right
  - Agile/waterfall project management
  - Extreme programming
    - Test driven development
    - Pair programming
  - ...
  - Some of these have ideas/techniques that are even useful in isolation

Iterative Development

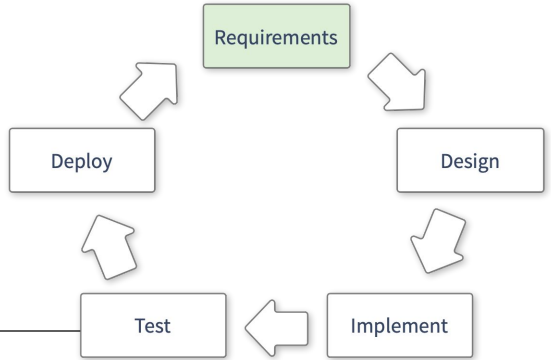


- General guidelines
  - Avoid duplication of work
  - Avoid feature bloating
  - Ensure code quality
  - Keep in mind: Software engineering relies heavily on communication!
    - Communication with the computer
    - Communication with your peers

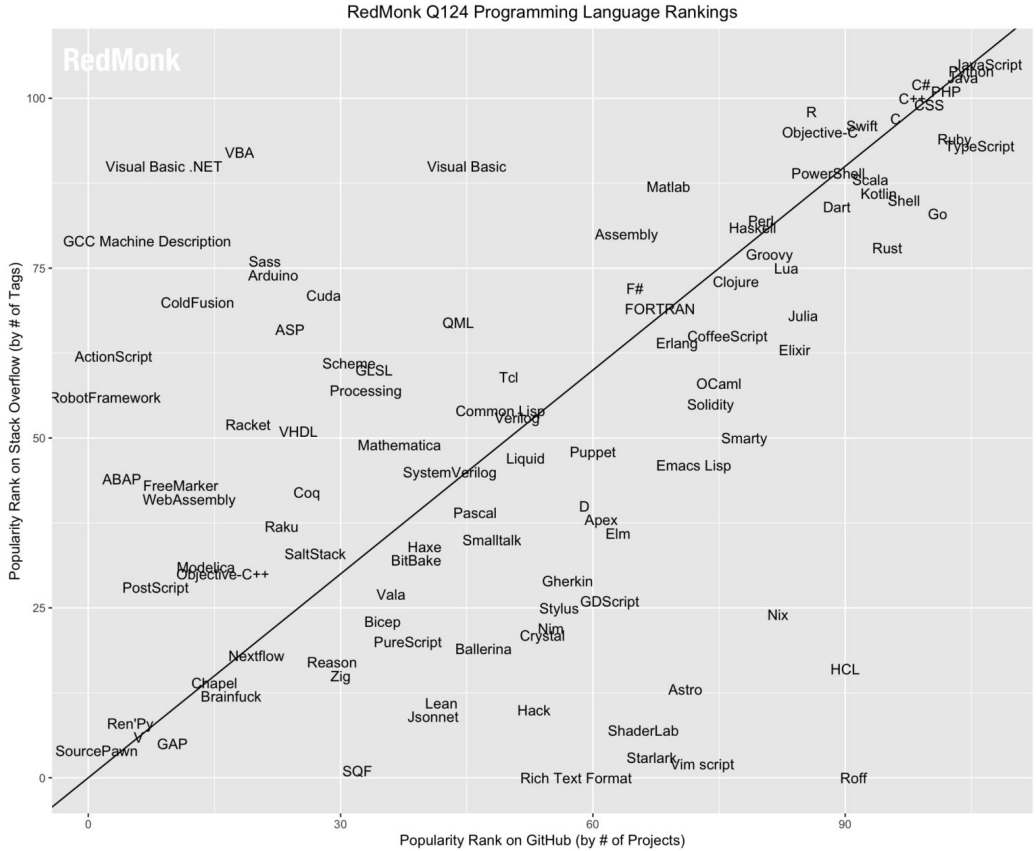
Test-Driven Development



Requirements



Choosing the programming language



Things to consider:

- Problem domain
  - Analysis?
  - DAQ?
- Popularity
  - The more people using the language the more questions already asked (and hopefully answered)

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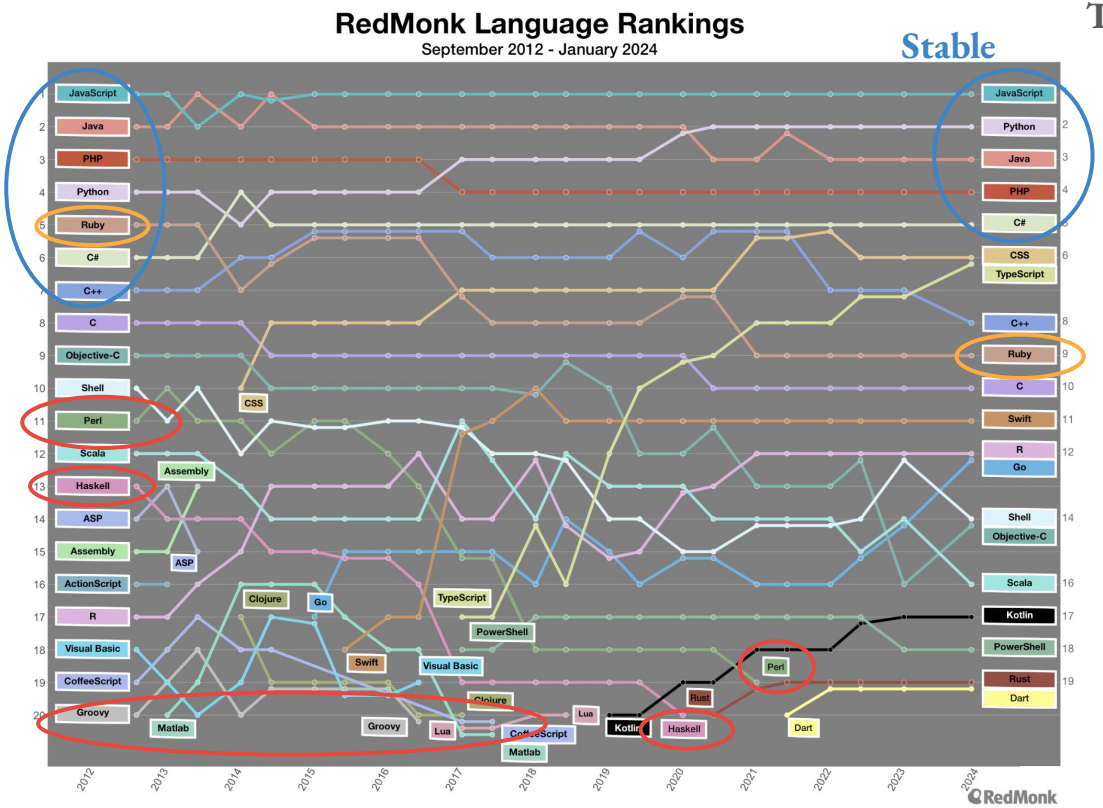

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- Documentation and support
  - Don't underestimate the utility of useful official docs

Choosing the programming language

Things to consider:

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  - DAQ?
- Popularity
  - The more people using the language the more questions already asked (and hopefully answered)
  - But it shouldn't be short lived...
- Documentation and support
  - Don't underestimate the utility of useful official docs
- **Can you choose?**
  - **Existing expertise in group**
  - Language support at workplace
- ...

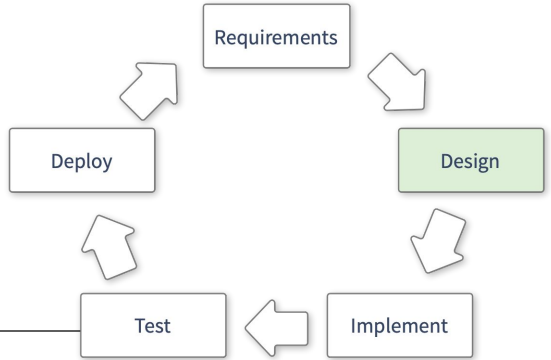
```
 ; g++ -std=c++17
g++: error: unrecognized command line option ‘-std=c++17’
```

```
 ; python3.9
zsh: command not found: python3.9
```

Do you really have to program?

Or has somebody already done it for you?

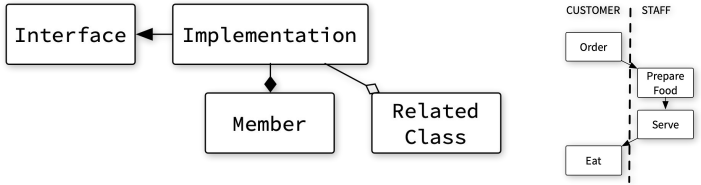
Design

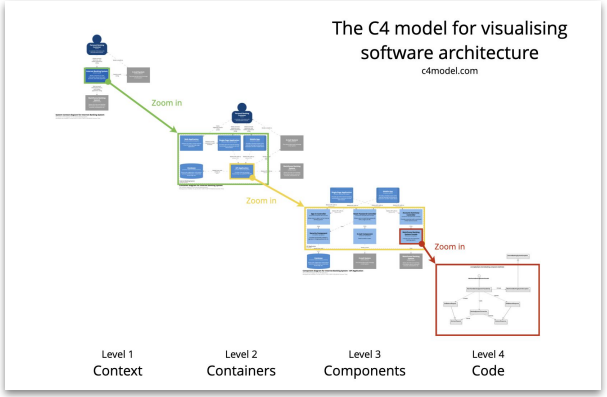


Plan ahead

Sketch out what you want to design

- Unified modeling language (UML) diagrams
  - Support for many types of diagrams
    - Structural, behaviour, interaction diagrams,...
  - Very powerful
    - Not very widespread nowadays, though...
- C4 model
  - Rather new arrival, but gaining popularity
  - Four levels of diagrams from "birds eye view" to "code level" diagram
    - UML used for lowest level code description





Write your first ideas out in pseudo-code

- Don't need to think about scope, initialisation, etc.
- Allows you to quickly put your thoughts to paper
  - Can be useful e.g., for algorithm design, when you want to spend your brain cycles on the problem, not on the tools

```
function find_local_optimum()
        while solution is not locally optimal do
                find s with f(s) < f(solution)
        return s
```

Things to keep in mind when designing

Goal

- Are you still building what was required?
- Are you adding unneeded features?

Maintainability

- Is it easy to adapt to changed environment?
- Can you cope with (slightly) changed requirements?

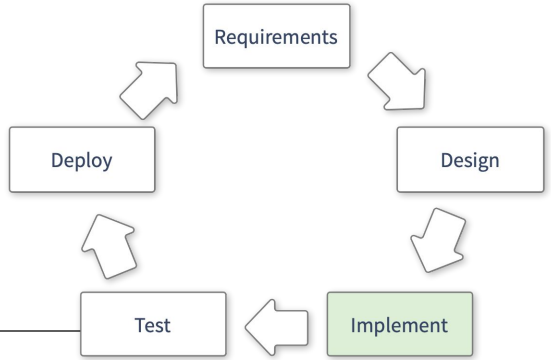
Scalability

- Large data volumes
  - Think about data-flow and data layout
  - Try to avoid complicated data structures

Re-usability

- Identify parts of the design that could be used elsewhere
- Could these be extracted in a dedicated library?

Implementation



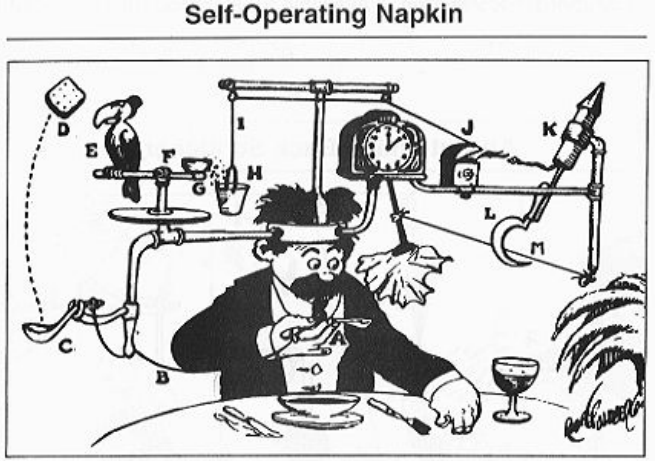
Do not reinvent the wheel

Look around for existing solutions

- Many problems have already been solved
- Look for libraries where:
  - Active community? Well maintained? Tested?
  - Rule of thumb: Last commit a few days ago, at most a year old
- Be wary of libraries with many features
  - Often come with lots of dependencies, increasing your attack surface, overall complexity, might slow down your code, ...
- Caveat: Don't pull in external code for trivialities
  - Almost no reason to use e.g., https://pypi.org/project/isEven/

Getting to know new frameworks:

- Read the docs
  - Investing time in the beginning will pay off
- python packages: try the ipython “help”
- Start with a simple test
  - Modify existing examples to do what you want to do
  - Does the code do what you expect?



“Prof. Lucifer Butts and his Self-Operating Napkin”,
by Rube Goldberg

Before searching for external libraries: Check out e.g., STL and Python standard library!

When coding: Avoid feature bloating

If you squeeze every conceivable feature in one place:

- You'll probably end up doing nothing right
- Write specialised toolkits/libraries

Define features by writing a test that needs to be passed

- Only implement what is strictly needed to pass that test

Be pragmatic

- Generalising a problem before solving it:
  - Probably not a good idea
  - Only do it when you have a use case
- Keep everything as concise as possible (increased readability)
  - Introduce abstraction only when likely to be actually used
- **Keep it as simple as possible!**

Tools of the Trade: Editor, Terminal and IDEs

Whatever you do, you'll end up using (at least)

- Editor
  - Know* at least one ubiquitous editor: nano, vi(m), emacs, etc.
  - More modern solutions: can make your life a lot easier..
  - Depending on the language/platform (e.g., Java): IDEs are a better choice (Eclipse, Netbeans, etc.)

- Terminal
  - Learn about shortcuts (minimal set: Tab, Ctrl+r, Ctrl+e, Ctrl+a,... have a look**)
  - Knowing about some basic command line-tools can come in handy

*at least how to exit them :-)

**https://ostechnix.com/list-useful-bash-keyboard-shortcuts/
or https://gist.github.com/tuxfight3r/60051ac67c5f0445efee

Some words on editors: Choose what suits you

The choice of editor is yours to make...

- Do you want
  - "a great operating system, lacking only a decent editor"
  - Or one with two modes: "beep constantly" and "break everything"*
- **Both are versatile and learning them is worthwhile**

However: **Modern alternatives have a less-steep learning-curve**

- Some are commercial (Sublime Text, TextMate,...)
- Some are (reasonably) open: e.g., Microsoft VSCode, Adob Brackets,...
  - Plugins, git integration, active communities, more plugins...

Once you decided which one is best for you:

- Spend some time learning about features and keybindings
- Many things that might require dozens of keystrokes can be done with 2
- Learn about: Linters, version control system integrations, and other plugins

*from The Editor War

The terminal

Initially: Clicking is faster than typing, no need for the terminal.

After learning about some command line tools… probably not.

- What if you don't have a GUI?
- Searching files: grep, find — example:
  - `$ grep -R -A 3 "foo" *`
    - Displays all matches of "foo" (+3 lines below) in all files in the current directory and its subfolders
  - Can be extended to only search files with certain ending
    - `$ find . -name "*.cc" -exec grep -A 3 "foo" {} +`
- Once you learn some tools it becomes very versatile:
  - **sed, head, tail, sort… awk** (a turing-complete interpreted language)
  - At the beginning: Note down often used commands…
  - After a tutorial dump your history* (increase cache size for max usage)

Shell scripting:

- **Anything you do with the shell can be put into a script**
- **Alternative:** Can solve most things more conveniently with an interpreted language
  - **Con:** Might not always be available where you need it

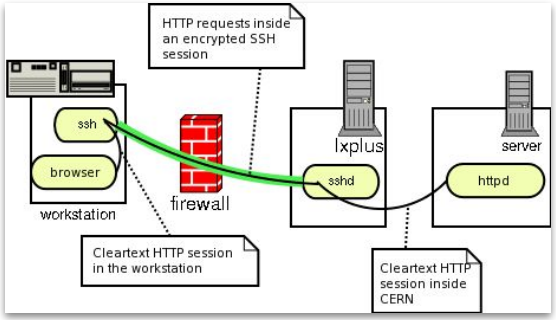
*to dump e.g., the last 100 commands:
`$ history | tail -n 100 > history.txt`

Bite size bash (few dollars, but quite useful):
https://wizardzines.com/zines/bite-size-bash/

Interlude: Working on the road — SSH

SSH — very, very versatile:

- **Tunneling**
  - Secure connections to other machines
  - Can e.g., establish secure connections to machines behind firewalls
- Keys for authentication instead of passwords
  - Makes life a bit more comfortable
  - **Alternative:** Login via Kerberos token if available*
- To work around shaky connections
  - Always use tmux/screen or a similar terminal multiplexer
- **SSHFS**
  - Files on remote host but "pretend" to be local



Lots of things possible with the ssh-config:

```
HOST <host>
    USER <remote-user>
    ProxyCommand ssh <tunnel> nc <host> <port>
```

More on (auto-)tunnelling:
https://security.web.cern.ch/security/recommendations/en/ssh_tunneling.shtml

tmux guides and courses:
https://robots.thoughtbot.com/a-tmux-crash-course
http://www.hamvocke.com/blog/a-quick-and-easy-guide-to-tmux/

* see e.g., https://linux.web.cern.ch/docs/kerberos-access/

The right tool for many jobs: Interpreted languages

Keep your code as short as possible while **maintaining readability**

- Sometimes means to use the right language
- Often these are interpreted languages
  - python, perl, ruby, tcl, lua
- Used as binding languages:
  - Performance critical code in C/C++
  - Instantiated within python
    (e.g. in CMS, ATLAS & LHCb offline software)
  - Best of both worlds
- Python: large standard library & very expressive!

```python
import click

months = {"january": 31, "february": 28, "march": 31,
          "april": 30, "may": 31, "june":30,
          "july": 31, "august": 31, "september": 30,
          "october": 31, "november": 30, "december": 31}

@click.command()
@click.option('--month', prompt='Which month are you interested in?',
              help='Print the number of days this month has.')
def print_days_in_month(month):
    """Simple program that states how many days MONTH has."""
    if month in months:
        print(f"{month} has {months[month]} days.")
    else:
        print(f"Sorry. Month {month} not known.")

if __name__ == '__main__':
    print_days_in_month()
```

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    (e.g. in CMS, ATLAS & LHCb offline software)
  - Best of both worlds
- Python: large standard library & very expressive!

```python
import click

months = {"january": 31, "february": 28, "march": 31,
          "april": 30, "may": 31, "june":30,
          "july": 31, "august": 31, "september": 30,
          "october": 31, "november": 30, "december": 31}

@click.command()
@click.option('--month', prompt='Which month are you interested in?',
              help='Print the number of days this month has.')
def print_days_in_month(month):
    """Simple program that states how many days MONTH has."""
    if month in months:
        print(f"{month} has {months[month]} days.")
    else:
        print(f"Sorry. Month {month} not known.")

if __name__ == '__main__':
    print_days_in_month()
```

```
$ python month_script.py --help
Usage: month_script.py [OPTIONS]

  Simple program that states how many days MONTH has.

Options:
  --month TEXT  Print the number of days this month has.
  --help        Show this message and exit.
```

The right tool for many jobs: Interpreted languages

Keep your code as short as possible while **maintaining readability**

- Sometimes means to use the right language
- Often these are interpreted languages
  - python, perl, ruby, tcl, lua
- Used as binding languages:
  - Performance critical code in C/C++
  - Instantiated within python
    (e.g. in CMS, ATLAS & LHCb offline software)
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```

```
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Usage: month_script.py [OPTIONS]

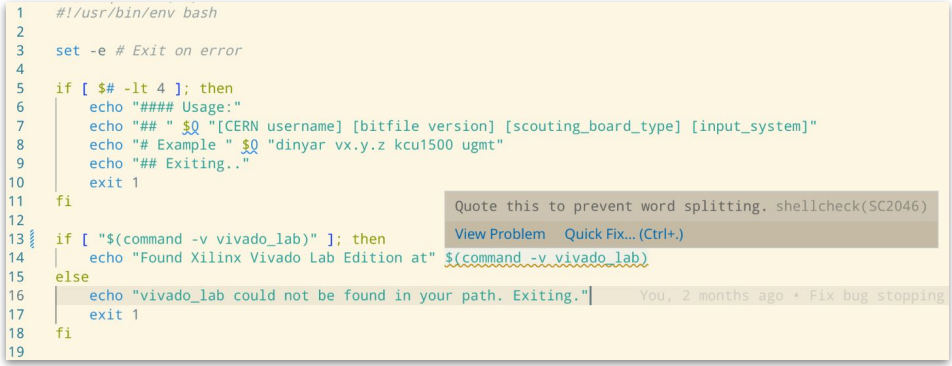
  Simple program that states how many days MONTH has.

Options:
  --month TEXT  Print the number of days this month has.
  --help        Show this message and exit.
$ python month_script.py --month november
november has 30 days.
$ python month_script.py
Which month are you interested in?: november
november has 30 days.
```

Static Code Checking

While writing your code:

- There are static code analysis tools that can help you
  - Like spell-check for your code
- Try out a linter for your preferred editor*
  - Highlights potentially problematic code
  - Your code will be more reliable



Static checking at compile time:

- Clang has a nice suite of static checks implemented**
  - Can also enforce coding styles
  - Takes longer than compiling; HTML reports with possible bugs
- Might flag some false-positives

Static code checking helps you avoid problems early on!

* Examples for VSCode:
Python: https://code.visualstudio.com/docs/python/linting
Shell: https://github.com/vscode-shellcheck/vscode-shellcheck

** see http://clang-analyzer.llvm.org

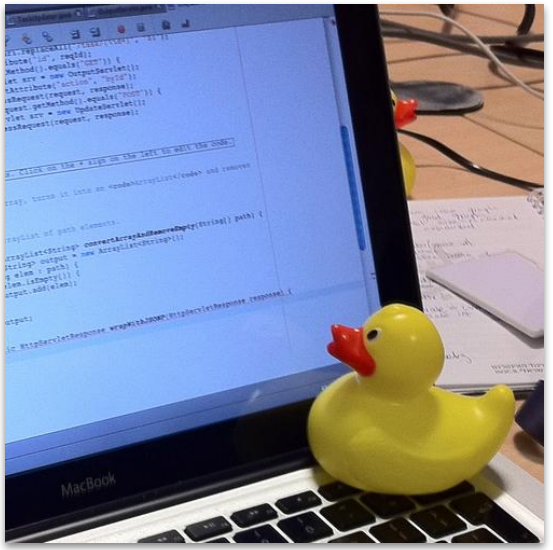
Debugging

- While running your code:
  - **Printing to console/log**: especially convenient if working in unfamiliar programming environment
    - This works for a surprisingly long time...
  - Sooner or later you'll want to use a debugger: e.g. **gdb (GNU debugger)**
    - basic commands: run, bt, info <*>, help
    - Very useful documentation in the Red Hat Developer Guides for e.g. RHEL7 and RHEL9
  - Python debugger (pdb, ipdb*, pygdb)
  - Under Linux: **strace**
    - To determine which system calls the program uses (and where they might be failing)
    - Use with: `strace <program name>`
    - Nice tutorials in the internet (e.g. https://opensource.com/article/19/10/strace)

```
* import ipdb
  ipdb.set_trace() # set a breakpoint
```

General hints for debugging

- Segmentation violations due to memory management
  - Life-time vs. scope
  - Look at smart pointers (part of C++11/14 standards, alternative: boost)
- Even if you don't have crashes: Memory Leaks, try valgrind
- When all else fails: Use a rubber duck
  - or invite your colleague for a coffee…
  - Verbalising a problem one has can often lead to a moment of epiphany



Documentation: Do it while it's fresh

Two sides of the same coin: embedded and standalone documentation

- Both necessary to make your programs easy to use
- They have different purpose!

Embedded documentation:

- Explain interfaces i.e., function signatures
- Make note of possible future problems (better: prevent them)
- Sometimes might be good to document your reasoning
- Do not "over comment"
  - Can at worst lead to "comment bugs"
- Clean code (almost) documents itself: **You write it once but you read it many times**

```python
class TheClass(object):
    """ Documentation of this class. """
    def __init__(self, var):
        self.var_ = var
    ## @var var_
    # my member variable


    ## Documentation of this function.
    # More on what this function does.
    ## @param arg1 an integer argument
    ## @param arg2 a string argument
    ## @returns a list of ...
    def some_function(self, arg1, arg2):
        pass
```

```python
if a > b: # when a is greater than b, do...
```

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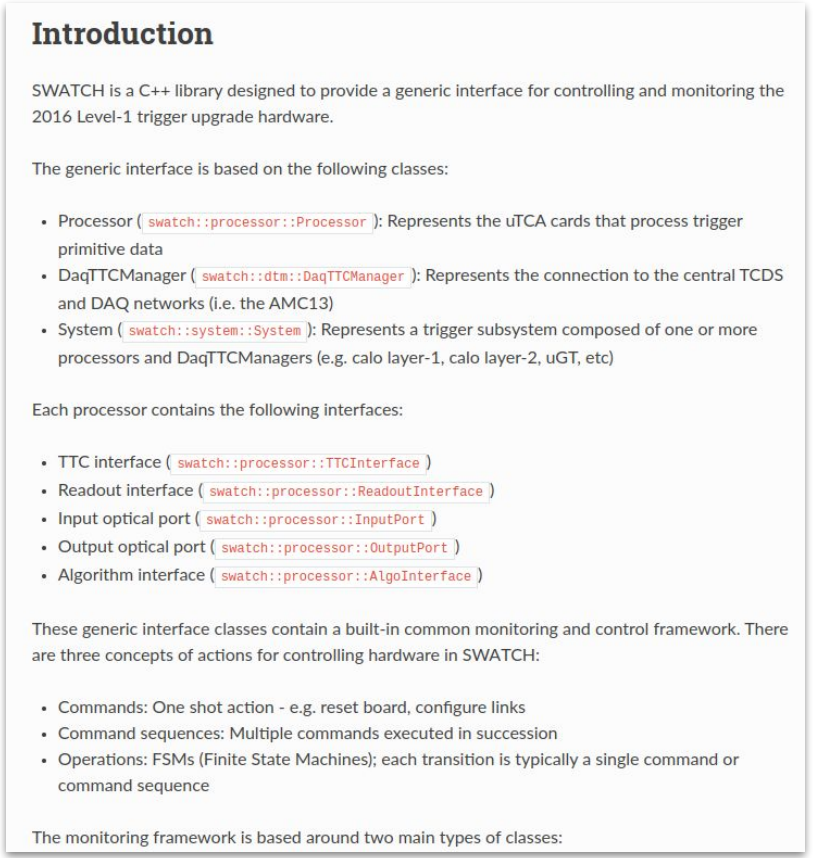
Standalone documentation:

- Again: Explain your interfaces (can be derived from internal, e.g. doxygen.org)
- For large projects: **Explain the big picture**
  - Give use-cases and examples
  - Consider using UML (unified modelling language) or other graphical notation techniques (e.g., the C4 model)



Introduction

SWATCH is a C++ library designed to provide a generic interface for controlling and monitoring the 2016 Level-1 trigger upgrade hardware.

The generic interface is based on the following classes:

- Processor (`swatch::processor::Processor`): Represents the uTCA cards that process trigger primitive data
- DaqTTCManager (`swatch::dtm::DaqTTCManager`): Represents the connection to the central TCDS and DAQ networks (i.e. the AMC13)
- System (`swatch::system::System`): Represents a trigger subsystem composed of one or more processors and DaqTTCManagers (e.g. calo layer-1, calo layer-2, uGT, etc)

Each processor contains the following interfaces:

- TTC interface (`swatch::processor::TTCInterface`)
- Readout interface (`swatch::processor::ReadoutInterface`)
- Input optical port (`swatch::processor::InputPort`)
- Output optical port (`swatch::processor::OutputPort`)
- Algorithm interface (`swatch::processor::AlgoInterface`)

These generic interface classes contain a built-in common monitoring and control framework. There are three concepts of actions for controlling hardware in SWATCH:

- Commands: One shot action - e.g. reset board, configure links
- Command sequences: Multiple commands executed in succession
- Operations: FSMs (Finite State Machines); each transition is typically a single command or command sequence

The monitoring framework is based around two main types of classes:

Documentation: Do it while it's fresh

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Standalone documentation:

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Step 2: Register subsystem-specific metrics

In the subsystem classes for processors and processor component interfaces (TTC, readout, input port, output port, and algorithm), you can add subsystem-specific metrics, which will then be accessible from the generic SWATCH API, and updated along with that object's common metrics. The new metrics are registered in the constructor of the subsystem-specific class, by calling one of the `registerMetric` methods, and their values must be set in the subsystem class' implementation of the `retrieveMetricValues()` method (in the same way as the values of the common metrics are set).

For example, a `uint16_t` counter for an input port - with "good" status for value of zero, error if the value is above 8, and warning otherwise - could be registered in the `MyInputPortClass` as follows:

- Add a reference to that type of metric as member data:

```
class MyInputPort {
  // ...
  // ...
  // ...

  swatch::core::Metric<uint16_t>& mMetricMySpecialCounter;
};
```

- Register that metric in the constructor:

```
MyInputPort::MyInputPort ( ... ) :
  swatch::processor::InputPort(stub),
  // ...
  mMetricMySpecialCounter( registerMetric<uint16_t>("specialCounter", swatch::core::GreaterThar
{
  // ...
}
```

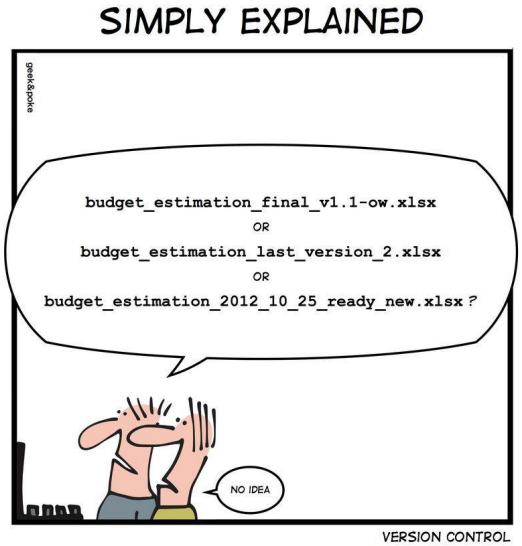
Always track code changes - Revision Control

Don’t underestimate the challenge of tracking your code

- Deceitfully simple at the beginning...
  - e.g.: zip/tar-based backups, versioning and distribution
- But the illusion is shattered soon enough
  - Upgrading tools or library, refactoring, rushing-in a patch
  - “Long-range” bugs are a thing, not always immediate to catch

Get familiar with Revision Control early

- Learn to track (and comment) every code change
- RCS is essential (and unavoidable) for collaboration

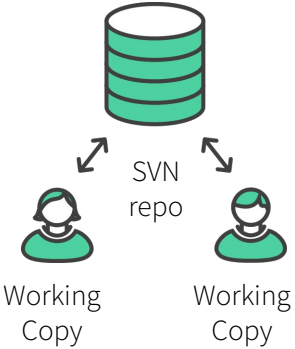


Version Control Software

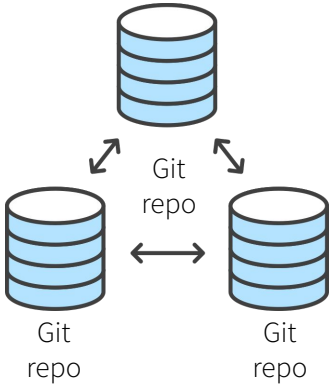
A software tool that helps you keep track of changes to your code

- Once upon a time: CVS and Subversion
- **Nowadays:** Distributed revision control – Great for personal use
  - Easy to work on the go
  - Your local copy has everything (including history)
  - The most popular probably git: git-scm.com
    - Other distributed solutions are: Mercurial, Breezy…
    - Easy to get started…

Central-Repo-To-Working-Copy Collaboration



Repo-To-Repo Collaboration



Interlude: git basics

```
$ git init
Initialized empty Git repository in /TestDirectory/.git/
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$ # Edit the file…
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$ git add README.md # Add the file to the index
```

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$ git init
Initialized empty Git repository in /TestDirectory/.git/
$ touch README.md # Create a readme file
$ # Edit the file…
$ git add README.md # Add the file to the index
$ git commit -m "Initial commit to my new repo"
```

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$ git init
Initialized empty Git repository in /TestDirectory/.git/
$ touch README.md # Create a readme file
$ # Edit the file…
$ git add README.md # Add the file to the index
$ git commit -m "Initial commit to my new repo"
$ # Create more files and edit them..
$ git add firstFile.txt sourceFile.cc headerFile.h
$ git commit -m "Short descriptive summary
dquote>
dquote> More expansive explanation of the commit,
dquote> if necessary."
```

How-to write good commit messages:
https://cbea.ms/git-commit/

Random github commit messages:
http://whatthecommit.com/

Interlude: git basics, avoid this:

Git in a nutshell

Learn basic concepts and commands

- Create repository, add file, commit new versions: `git (init, add, commit)`

Familiarise yourself with parallel development concepts

- Switch to branches or create new ones: `git (switch [-c]/checkout [-b])`
- Merging and rebasing: `git (merge, rebase)`

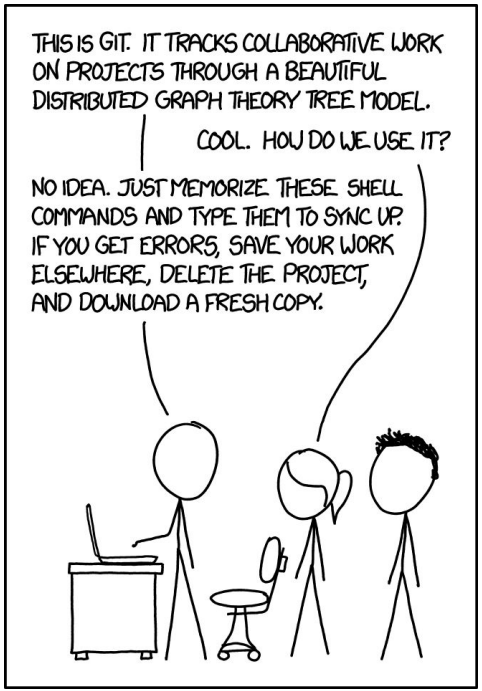
Learn how to interact with remote repositories and users

- Retrieve and share code: `git (clone, pull, push, fetch)`

Very powerful system means there is inherent complexity

- It is entirely possible to use restricted feature set and be very productive!

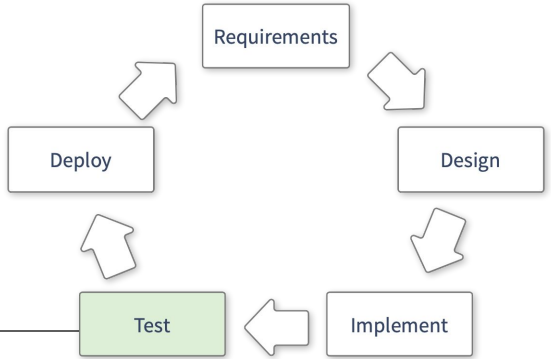
Still worth spending some time reading about it!*



Git tutorials:
http://git-scm.com/book/en/v2/Getting-Started-About-Version-Control
http://pcottle.github.io/learnGitBranching/

*Ultimate git guide: https://jwiegley.github.io/git-from-the-bottom-up/

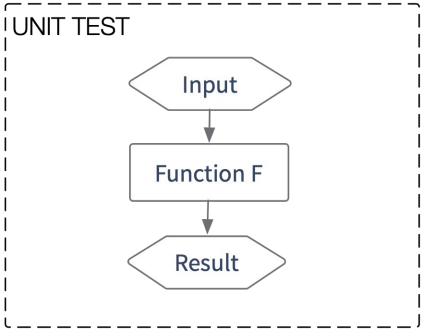
Testing

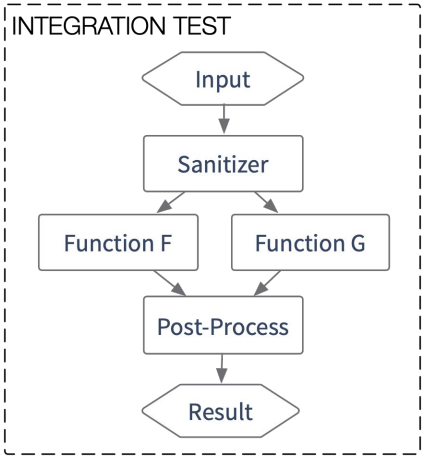


What do we mean with tests?

Different tests, different purposes:

- Unit test
  - Testing “units of code”, e.g. a function or class
  - Given a defined input → expected output?
- Integration test
  - Testing a larger part of your software
  - For example running an example and checking output





Modifying code base that is well-covered by tests is infinitely more fun than one that is almost untested!

Do not confuse it with verification

Checks if specifications are met

Writing good tests is hard

How to come up with tests?

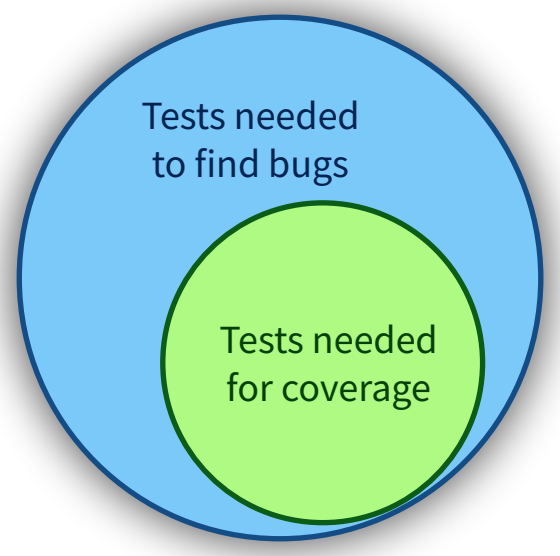
- What should the algorithm do?
  - Check if well defined input produces correct result
- How should the algorithm fail?
  - Check if wrong input fails in the way you want

You'll ~~probably~~ miss corner cases

- Once you discover them, implement a test!
  - **Only let a bug hit you once**
- Have users help you
  - Use issue tracker
  - Be responsive!

Look at existing solutions to implement tests

- Python: doctest and unittest packages
- C++: CTest (integrated with cmake) & Catch



Interlude: doctest

```
$ python testfib.py
```

```
def fib(n):
    """ Returns the fibonacci series at n
    >>> [fib(n) for n in range(6)]
    [0, 1, 1, 2, 3, 5]
    >>> fib(-1)
    Traceback (most recent call last):
      ...
    ValueError: n should be >= 0
    """
    if n < 0:   raise ValueError("n should be >= 0")
    if n == 0:  return 0
    a, b = 1, 1
    for i in range(n-1):
        a, b = b, a+b
    return a

import doctest
doctest.testmod()
```

Interlude: doctest

```
$ python testfib.py
$ # No error → All tests passed!
```

```
def fib(n):
    """ Returns the fibonacci series at n
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    >>> fib(-1)
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Interlude: doctest

```
$ python testfib.py -v
```

```
def fib(n):
    """ Returns the fibonacci series at n
    >>> [fib(n) for n in range(6)]
    [0, 1, 1, 2, 3, 5]
    >>> fib(-1)
    Traceback (most recent call last):
      ...
    ValueError: n should be >= 0
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    return a

import doctest
doctest.testmod()
```

Interlude: doctest

```
$ python testfib.py -v
Trying:
    [fib(n) for n in range(6)]
Expecting:
    [0, 1, 1, 2, 3, 5]
ok
Trying:
    fib(-1)
Expecting:
    Traceback (most recent call last):
      ...
    ValueError: n should be >= 0
ok
1 items had no tests:
    __main__
1 items passed all tests:
   2 tests in __main__.fib
2 tests in 2 items.
2 passed and 0 failed.
Test passed.
```

```
def fib(n):
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    return a

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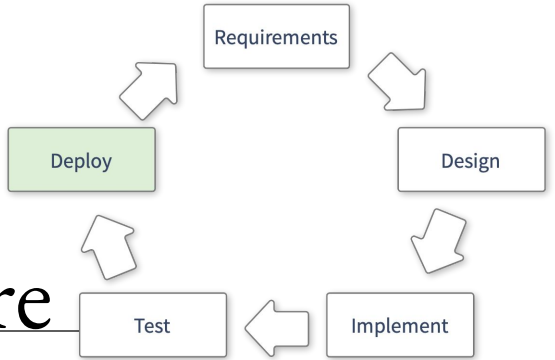
See https://docs.python.org/3/library/doctest.html for more examples and explanations!

Deploying your software

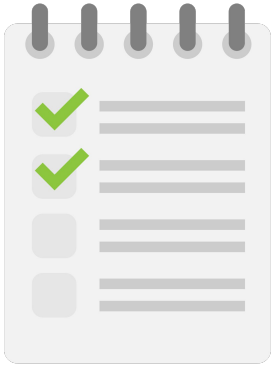


Releasing the Software

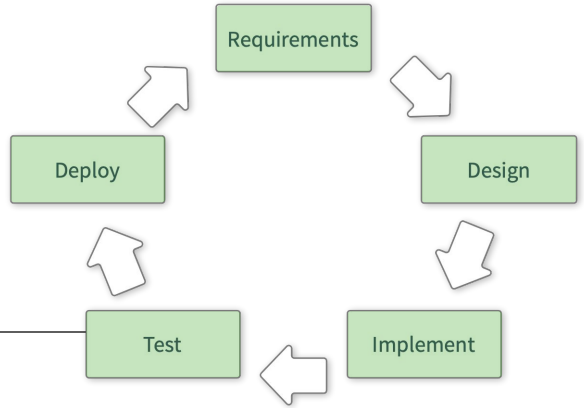
When you release your software:

- Tag the repository
  - Defines a common "checkpoint"
- Test in the target environment
  - In e.g., fresh virtual machine or docker container
  - If you test locally you might be unknowingly using private files/variables
- Create/release accompanying documentation
  - Produce e.g., Doxygen pages
  - Update wikis or whatever documentation pages you use (tag a new version)
  - Make sure all examples work

Ideal case: All this is done automatically!



Automate

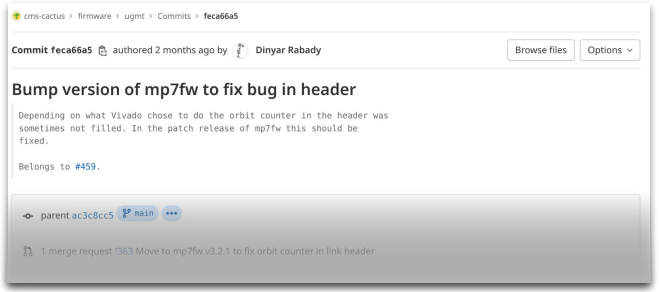


Goal

We would like to

- Commit some code

and then **automatically** make it ready for deployment.



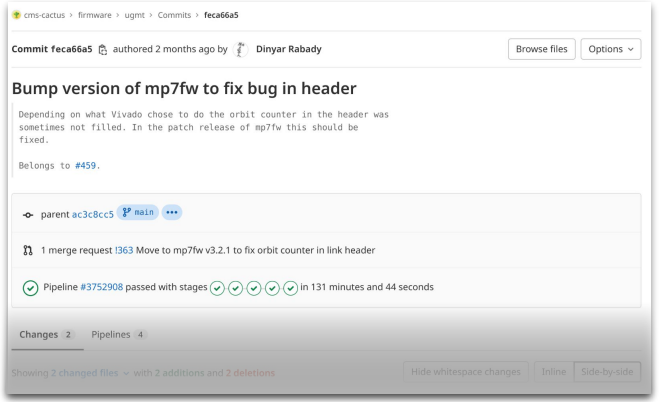
Goal

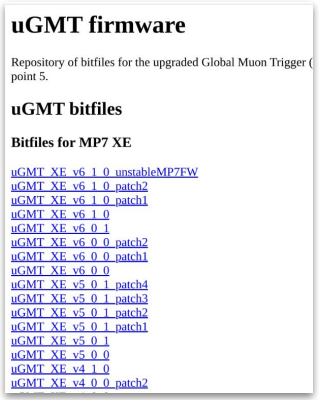
We would like to

- Commit some code

and then **automatically** e.g.,

- Test
  - e.g., Unit tests
- Build
- Package the products and name them
  - e.g., RPM, JAR, tar/zip archives, ...
- Test again
  - e.g., Integration tests
- Provide the packages for deployment
  - OR... deploy them immediately





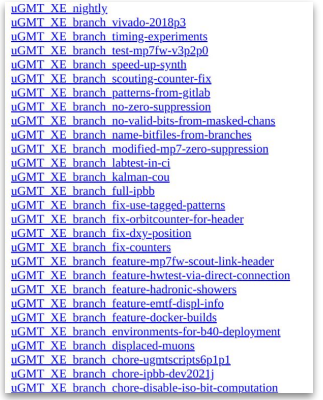
uGMT firmware

Repository of bitfiles for the upgraded Global Muon Trigger (point 5.

uGMT bitfiles

Bitfiles for MP7 XE

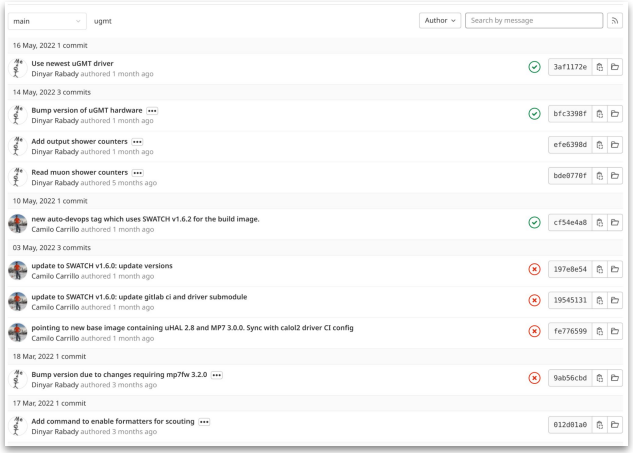
uGMT_XE_v6_1_0_unstableMP7FW
uGMT_XE_v6_1_0_patch2
uGMT_XE_v6_1_0_patch1
uGMT_XE_v6_1_0
uGMT_XE_v6_0_1
uGMT_XE_v6_0_0_patch2
uGMT_XE_v6_0_0_patch1
uGMT_XE_v6_0_0
uGMT_XE_v5_0_1_patch4
uGMT_XE_v5_0_1_patch3
uGMT_XE_v5_0_1_patch2
uGMT_XE_v5_0_1_patch1
uGMT_XE_v5_0_1
uGMT_XE_v5_0_0
uGMT_XE_v4_1_0
uGMT_XE_v4_0_0_patch2



uGMT_XE_nightly
uGMT_XE_branch_vivado-2018p3
uGMT_XE_branch_timing-experiments
uGMT_XE_branch_test-mp7fw-v3p2p0
uGMT_XE_branch_speed-up-synth
uGMT_XE_branch_scouting-counter-fix
uGMT_XE_branch_patterns-from-gitlab
uGMT_XE_branch_no-zero-suppression
uGMT_XE_branch_no-valid-bits-from-masked-chans
uGMT_XE_branch_name-bitfiles-from-branches
uGMT_XE_branch_modified-mp7-zero-suppression
uGMT_XE_branch_labtest-in-ci
uGMT_XE_branch_kalman-cou
uGMT_XE_branch_full-ipbb
uGMT_XE_branch_fix-use-tagged-patterns
uGMT_XE_branch_fix-orbitcounter-for-header
uGMT_XE_branch_fix-dxy-position
uGMT_XE_branch_fix-counters
uGMT_XE_branch_feature-mp7fw-scout-link-header
uGMT_XE_branch_feature-hwtest-via-direct-connection
uGMT_XE_branch_feature-hadronic-showers
uGMT_XE_branch_feature-emtf-displ-info
uGMT_XE_branch_feature-docker-builds
uGMT_XE_branch_environments-for-b40-deployment
uGMT_XE_branch_displaced-muons
uGMT_XE_branch_chore-ugmtscripts6p1p1
uGMT_XE_branch_chore-jnbb-dev2021j
uGMT_XE_branch_chore-disable-iso-bit-computation

But why?

- Reduces work
  - **Committing** to repository **is enough**
    - Tests are run
    - Builds are performed
    - Product provided for download
- Possibility for non-experts to build complex or resource intensive software or firmware
  - **Added bonus:** Per construction there is a recipe to build your code in the repository!
- Consistent record of your development
  - With **indication** whether particular **revision is known to be good**
- Gives confidence
  - **"Spatial":** Does my work build correctly on other machines?
    - e.g., Did I commit everything required to my repository?
  - **"Temporal"**: Is this particular commit from two years ago supposed to work?
- Ensures consistency of a given package
  - We **know** that this was built with *these* libraries and in *this* environment

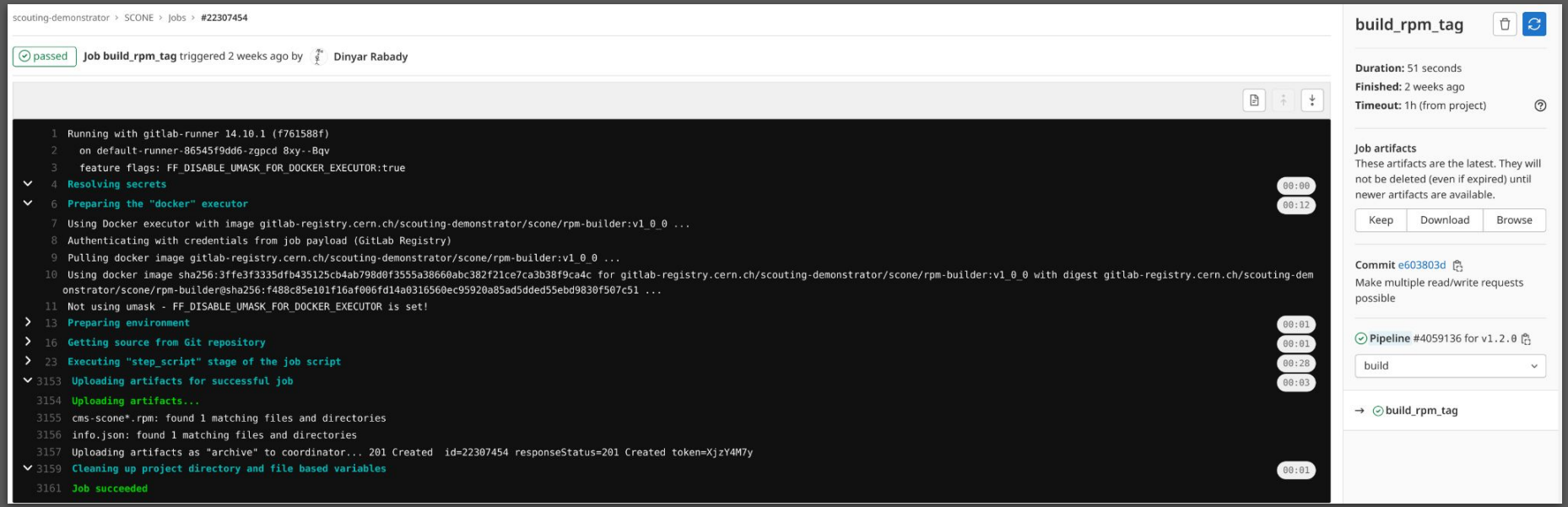


Interlude: Gitlab CI

```
$ cat .gitlab-ci.yml
image: gitlab-registry.cern.ch/scouting-demonstrator/scone/rpm-builder:v1_0_0

build_rpm_tag:
  stage: build
  only:
    - tags
  script:
    - bash build.sh
    - bash package.sh
  artifacts:
    name: "scone-${CI_JOB_NAME}_${CI_COMMIT_TAG}"
    paths:
      - cms-scone*.rpm
      - info.json
    expire_in: 1 week
```

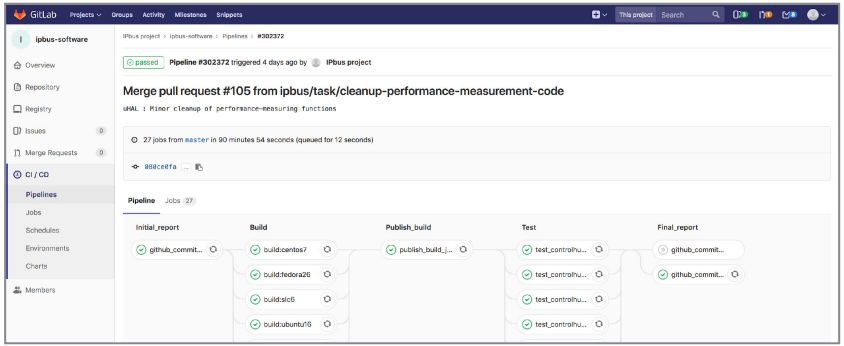
Interlude: Gitlab CI



For resource intensive builds/tests or other special requirements for the running machine: Can set up specialised runners (i.e., "computers that run your jobs").

See https://docs.gitlab.com/ee/ci/ for a complete documentation!

Many solutions available for this…



Gitlab CI - https://about.gitlab.com/features/gitlab-ci-cd/

Travis CI - https://travis-ci.org

Also https://www.jenkins.io/, https://circleci.com/, https://docs.github.com/en/actions/automating-builds-and-tests/about-continuous-integration, …

Words of advice

- Well designed **build tools are crucial**
  - Invaluable even when not using continuous integration
    - Essential when using it
- Some measure of discipline required to get the most out of this
  - Build system requires some time to set up
    - **Very good investment**, but initially somewhat frustrating
  - Continuous integration most useful if actually used regularly
    - If you put each code change into your repository you can later come back and check what was the breaking change
- Spend time finding the right development process for you(r team)
  - Use of tags?
  - Use of branches?
  - Pull/Merge requests?
  - ...
  - Lots of "standard" processes around (Gitflow, trunk-based,...)
    - Significant experience probably also around your lab (and coffee is cheap)
- Above all: **Don't get overwhelmed by the possibilities!**
  - Start simple!

General tips & pointers

Learning about software development

Coursera and Udacity

- https://www.coursera.org/courses
  - Large variety of courses
    - Not only technology / programming
    - Also physics, biology, economics... and more
    - Also in different languages
- https://www.udacity.com/courses/all?price=Free
  - Mixed courses: Some free, recently switched to a paid model with monthly fees

University Homepages — have a look, many courses available through YouTube etc.

- e.g.: Programming Paradigms, Stanford University
- https://www.edx.org/search?tab=course

Conclusion

These slides were full of starting points: You have to follow up to get something out of it

- Most of it are tools to make your life easier
- Nothing is free
  - You'll have to invest some effort to learn, but most tools shown here bring benefits very early in the learning curve!
- Many more tools to discover, lots of fun to be had with them!

Homework:

- Install git, start a repository. Try branching on the web
- Run tmux, kill the connection, reconnect and see if you can continue where you left off
  - **Beware:** If you use a service like lxplus you get a machine from a pool (e.g. lxplus769) → Tmux/screen is running on that one!
- Tune your .bashrc / .bash_profile to get a more useful prompt
  - You can try e.g. oh-my-bash or oh-my-zsh, depending on the shell you are using
- Try out vim/emacs/vscode and learn what suits you best
  - Download a shortcut summary…
  - Learn how to block-select, indent multiple lines, rename occurrences of text