Clean Code with Python

A tour through techniques, projects and examples

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Introduction

What we need

- Examples use Python 3
- Editor with Python support
- You will get all material in a zip file shortly after the course

Approach

We will use three components:

- documents (instead of slides), exploring topics
- code examples
- coding tasks
- questions (and answers) in a shared pad (etherpad)

We can (and should) detour into specific questions any time.

Inspiration: Books on real software development, like "Clean Code" or the "Practice of Programming"

Books

- Clean Code
- The Practice of Programming
- Clean Code in Python
- Refactoring
- …

Clean code is not a single thing

- while popularized by Robert C. Martin, it is not *one thing*
- more like: "small things matter", or *small things add up*

> […] attentiveness to detail is an even more critical foundation of professionalism than is any grand vision [CC]

> Writing clean code requires the disciplined use of a **myriad little techniques** applied through a painstakingly acquired sense of "cleanliness." [CC]

Inspiration comes from a broad literature on software engineering and other fields:

- Patterns research community (design patterns)
- Research Labs (e.g. Bell Labs)

Architecture:

- Christopher Alexander, A pattern language (1977)

Japanese production lines: Total Productive Maintenance (TPM) using **5S** (1950-1970):

- Seiri - "sort", "know where things are"
- Seiton - "systematize", "tidyness", a place for everything and everything in its place
- Seiso - "shine", keep the work place free of handing wires, waste, …
- Seiketsu - "standardization", consensus on how the workplace is kept clean
- Shutsuke - "self-discipline", follow rules over time

Fred Brooks (IBM):

- rewrite every seven years (to cleanup up)
- example: an popular maps web application is at least at its second complete rewrite

Many practicioners can be be quoted (from various fields):

> preoccupation with *detail* is common to all endeavors of excellence

Interestingly, a classic CS education does not necessarily go into these kind of (coding) details.

Programming as a loser's game

- hypothesis: software development is *loser's game* (article)
- analogy from (amateur and expert) tennis (Charles Ellis, 1970's, investing context)

> "In expert tennis, about 80 per cent of the points are won; in amateur tennis, about 80 per cent of the points are lost. In other words, professional tennis is a Winner's Game — the final outcome is determined by the activities of the winner — and amateur tennis is a Loser's Game — the final outcome is determined by the activities of the loser. The two games are, in their fundamental characteristic, not at all the same. They are opposites." Charles Ellis

- you win by avoiding mistakes (and not necessarily by being extraordinary)

Dogma

- while there are rules and techniques, following a dogma blindly will probably not help
- teams with underspecified process can win, teams working *by the book* can fail
- there is a balance between business and software needs, that is a challenge to find and keep

Overview

What is clean code?

Before we dive in, what is our take?

- Please, go to the pad and answer briefly, or with keywords:

> Question: How would you describe clean code? Which properties would it have?

What other people say

The Book let's a few people speak.

> I like my code to be elegant and efficient. The logic should be straightforward to make it hard for bugs to hide, the dependencies minimal to ease maintenance, error handling complete according to an articulated strategy, and performance close to optimal so as not to tempt people to make the code messy with unprincipled optimizations.

> **Clean code does one thing well.** – Bjarne Stroustrup

> Clean code is simple and direct. Clean code **reads like well-written prose**. Clean code never obscures the designer's intent but rather is full of crisp abstractions and straightforward lines of control. – Grady Booch

This emphasis of readability relates to *Readability counts.* from the Zen of Python.

> Clean code can be read, and **enhanced** by a developer other than its original author. It has **unit and acceptance tests**. It has **meaningful names**. It provides **one way** rather than many ways for doing one thing. It has **minimal dependencies**, which are explicitly defined, and provides a clear and minimal API. Code should be literate since depending on the language, not all necessary

> information can be expressed clearly in code alone. – Dave Thomas

> I could list all of the qualities that I notice in clean code, but there is one overarching quality that leads to all of them. **Clean code always looks like it was written by someone who cares**. There is nothing obvious that you can do to make it better. All of those things were thought about by the code's author, and if you try to imagine improvements, you're led back to where you are, sitting in appreciation of the code someone left for you—code left by some- one who cares deeply about the craft. – Michael Feathers

> You know you are working on clean code when each routine you read turns out to be **pretty much what you expected**. You can call it beautiful code when the code also makes it look like the language was made for the problem. – Ward Cunningham

Software Engineering and Programming

Software engineering has been described as programming over time, subjected to deadlines.

- Boy scout rule: Leave the campground cleaner than you found it

Imagine checking code in, that is a tiny bit cleaner, more streamlined, better documented, with fewer bugs than at checkout time. Code would only get better. # Motivation: Software that fits your problem

Overengineering

> 20K LOC for something that may be command line tool

too much design for a problem

Underengineering

- everything lives in function in a language that supports OO
- no functions at all (single file, top to bottom, 15K lines)

Let us do the job before we get regulated

- software is volatile
- first SW engineering conference took place in 1968

Software is still complex, software is a losers game

- you can win by just avoiding some bad practices

Pragmatic Python

- Some patterns are not required, because Python is expressive
- Keep it pragmatic, use magic sparingly

Clean Code critique

- stop recommending clean code: article

Disclaimer

what do you prefer?

- clean code, no revenue, or
- spaghetti code making a million a month

Writing software is a complex activity

> Writing software is a complex activity and we should respect that, when we talk about it, when we discuss all matters software# Clean Code Principles

Classic software failures

- projects go over budget
- companies spend millions and end up nowhere
- bad software causes fatalities, impacts revenue, and can pose generic risks, e.g. security incidents

A 2015 article in IEEE spectrum:

- Transistor Production Has Reached Astronomical Scales

Every second of 2014, on average 8 trillion transistors were produced. It is some software that will run on these.

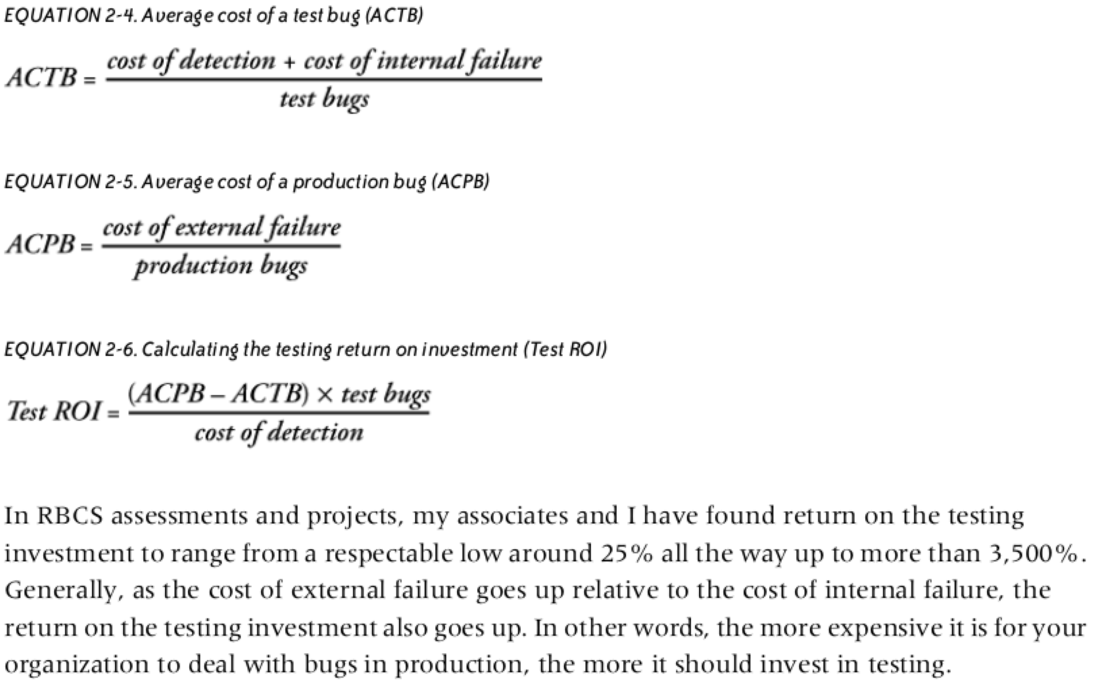
Robert C. Martin motivation: Let us cleanup ourselves before we are going to be hit by regulation.

We are living in the age of data, so here's a quip on data and code:

> Code ages like fish, data ages like wine.

Calculating failure costs

- ROI on testing
- How much time can you invest in testing - or improving code in general?



EQUATION 2-4. Average cost of a test bug (ACTB)

$$ACTB = \frac{\textit{cost of detection} + \textit{cost of internal failure}}{\textit{test bugs}}$$

EQUATION 2-5. Average cost of a production bug (ACPB)

$$ACPB = \frac{\textit{cost of external failure}}{\textit{production bugs}}$$

EQUATION 2-6. Calculating the testing return on investment (Test ROI)

$$\textit{Test ROI} = \frac{(ACPB - ACTB) \times \textit{test bugs}}{\textit{cost of detection}}$$

In RBCS assessments and projects, my associates and I have found return on the testing investment to range from a respectable low around 25% all the way up to more than 3,500%. Generally, as the cost of external failure goes up relative to the cost of internal failure, the return on the testing investment also goes up. In other words, the more expensive it is for your organization to deal with bugs in production, the more it should invest in testing.

Clean code layers (top down)

- Architecture
- Patterns
- Data Structures
- Idiomatic Code

The right architecture and approach

- rarer, but important decisions
- try to postpone hard questions regarding design
- sometimes Worse is better

> Worse is better (also called the New Jersey style) is a term conceived by Richard P. Gabriel in an essay of the same name to describe the dynamics of software acceptance. It refers to the argument that software quality does not necessarily increase with functionality: that there is a point where less functionality ("worse") is a preferable option ("better") in terms of practicality and usability.

Useful patterns

- code reuse (i.e. find a suitable library)
- tool reuse ("Taco Bell", article)

> The more I write code and design systems, the more I understand that many times, you can achieve the desired functionality simply with clever reconfigurations of the basic Unix tool set. After all, functionality is an asset, but code is a liability. […] Every time you write code or introduce third-party services, you are introducing the possibility of failure into your system.

- convention over configuration

The right data structures

- worry about data structures
- rather 1 data structure and 100 methods than 10 with 10 each

Idiomatic code (readability)

- make code look boring
- make wrong code look wrong
- Perl ("there is more than one way to do it") to Python ("There should be one– and preferably only one –obvious way to do it")
- use the language (to your advantage)

Cross-cutting concern

Worry about things that are not directly code, like deployment, continuous test and build processes, etc.

- software lifecycle and support
- CI
- testing
- docs (developer, external, …)
- setup

Learn from open source projects

- pragmatic
- efficient
- documented

There is plenty wrong with OSS as well, but successful project can be an inspiration.

- Companies switch (or switched) to basically a common open source workflow when they adopted hosted git server applications

SW engineering's greatest hits

- Software Engineering's Greatest Hits, Slides

What does research says about software development practices?

- novice errors
- TDD studies
- code metrics

> But nothing works better than counting lines of code

- error handling

> Majority of catastrophic failures could easily have been prevented by performing simple testing on error handling code

- exceptions

> Most common catch block logs the error rather than trying to recover from it

And the list goes on.

Good code properties

There are generic ideas and approaches that have been suggested to improve code quality.

- Question (Pad):

> Name one you would attribute to describe good code and one to less good code

Design by contract

- Betrand Meyer, 1980s
- Programming language: Eiffel
- deferred PEP-361 (2003): https://peps.python.org/pep-0316/
- https://github.com/Parquery/icontract

Example: [Snippets/Contracts]

Without specific contract library:

- makeing properties explicit with assertions or explicit checks (and e.g. raising `ValueError` on failures)

Defensive programming

Design to […] ensure the continuing function of a piece of software under unforeseen circumstances.

This can mean:

- focus on absence of errors
- readable, auditable code
- extra care when dealing with I/O

Error handling

- catch specific errors (avoid empty except)
- handle some gracefully
- fail fast

Find the *right level* for your exception.

- reuse existing exception hierarchy: https://docs.python.org/3/library/exceptions.html

You can include original exceptions via PEP-3134 - "Exception Chaining and Embedded Tracebacks"

> Example: [Snippets/ExceptionChaining]

> [...] implicit exception context can be supplemented with an explicit cause by using from with `raise`.

Use sensible default values

- across various layers
  - command line flags
  - keyword arguments

Use language facilities, like:

```
dict.get(key, default)
```

Assertions

- `assert`
- assertions as a last resort (e.g. halt program instead of handling an error)

Can be disable at runtime, e.g. with `python -O script.py`

```
$ python -c "assert False"
Traceback (most recent call last):
  File "<string>", line 1, in <module>
AssertionError
```

With basic optimizations:

```
$ python -Oc "assert False"
```

Encapsulation

- module interfaces should be simpler than the implementation

In Philosophy of Software Design Ousterhout reports various issues in implementations:

- students wrote too many classes for the problem - information leakage between classes; e.g. two classes to handle HTTP requests - hence both classes implemented many aspects of understanding the request data structure

> slightly larger classes could have helped to hide information (details about the request) better

Separation of concerns

Avoid adding to many responsibilities Case study: A DSL coupled with a backend storage system (SM).

Cohesion and coupling

- cohesion: well defined purpose; coupling: dependency between code
- aim for: high cohesion and low coupling ("oss" - separate parts, …)

DRY

- don't repeat yourself
- there is also the *rule of three* - use opportunities to abstract or factor out a piece of code

YAGNI

- related to TDD a bit
- what you need vs what you want
- some instances: abstracting backends (albeit only one is and will be used)
- any *potential* benefit

> It can be hard to distinguish between design and YAGNI

KISS

- from aerospace industry

> "Our aim," he said, "is to get results cheaper, sooner, and better through application of common sense to tough problems. If it works, don't fix it." "Keep it simple, stupid—KISS—is our constant reminder." – Biographical Memoir

Smallest data structure to fit the problem Quick question:

You are tasked to implement depth-first search on a graph. How could you implement a graph?

EAFP and LBYL

Python prefers the style: easier to ask for forgiveness than permission, or EAFP for short.

Example:

```
data = {
    "a": 1,
    "b": 2,
}

# Works, LBYL style (https://docs.python.org/3/glossary.html#term-lbyl)
if data.has_key("a"):
    v = data["a"]
else:
    do_something_else()

# Better, following EAFP (https://docs.python.org/3/glossary.html#term-eafp)
try:
    v = data["a"]
except KeyError:
    do_something_else()
```

Composition and inheritance

Example for sensible inheritance:

- socketserver and http packages: socketserver.py, server.py

```python
"""
...
There are five classes in an inheritance diagram, four of which represent
synchronous servers of four types:
        +------------+
        | BaseServer |
        +------------+
              |
              v
        +-----------+        +------------------+
        | TCPServer |------->| UnixStreamServer |
        +-----------+        +------------------+
              |
              v
        +-----------+        +--------------------+
        | UDPServer |------->| UnixDatagramServer |
        +-----------+        +--------------------+
...
"""

class HTTPServer(socketserver.TCPServer):

    allow_reuse_address = 1    # Seems to make sense in testing environment

    def server_bind(self):
        """Override server_bind to store the server name."""
        socketserver.TCPServer.server_bind(self)
        host, port = self.server_address[:2]
        self.server_name = socket.getfqdn(host)
        self.server_port = port


class ThreadingHTTPServer(socketserver.ThreadingMixIn, HTTPServer):
    daemon_threads = True
```

A mixin here adds threading functionality (but not more).

Inheritance related anti-patterns

- Anemic Domain Model
  - data and related behaviour in two separate classes

- BaseBean (no beans in Python, though)
  - you may inherit from a dictionary to get lookup functionality (rather, use a dictionary)
- Circle-Ellipsis problem (or Square-Rectangle Problem) - violated LSP ([…] It is only when derived types are completely substitutable for their base types […])

Multiple inheritance and MRO Python allows multiple inheritance.

- methods are resolved using C3 algorithm

Can make it easy to combine functionality:

```
class LoggingDict(dict):
    def __setitem__(self, key, value):
        logging.info('Setting %r to %r' % (key, value))
        super().__setitem__(key, value)

class LoggingOrderedDict(LoggingDict, collections.OrderedDict):
    pass
```

Mixins

- Mixins do provide partial functionality
- Example: ThreadingMixIn

Functions and arguments

- anything that can be derived should not be passed separately (request)
- use the already aggregated object

```
def f(request.header, request.body):
  pass

def f(request):
  header = request.header
  body = request.body
```

- or use some convential form

Example:

- instead of `f(filename, fh): pass` you can decide, whether you need the filename and file handle as separate parameters

Too many arguments lead to higher coupling

- in general, too many arguments lead to higher coupling
- in python, keyword (default) arguments are your friend (example: pandas.read_csv)

Group parameters

- similar to the request example
- for example config or "option" objects

Package design

- setup.py

Packaging options

- linkedin example: shiv

Automation with gitlab

```
# git push sc master => runs CI
#
# git tag v0.1.2
# git push sc --tags => creates package and uploads to Nexus

image: python:3.9.6-slim-buster

stages:
  - test
  - deploy

before_script:
   - pip install --upgrade pip
   - pip install pytest twine

tests:
  stage: test
  script:
    - pip install backports.csv # try installing this from pypi, nexus may
 ↪  not like the [.]
```

```
    - python setup.py develop --index-url $PYPI_PROXY_URL # faster, less load for pypi
    - pytest
  tags: [docker]
  except:
    - tags

upload_to_nexus:
  stage: deploy
  variables:
    TWINE_USERNAME: $NEXUS_USERNAME
    TWINE_PASSWORD: $NEXUS_PASSWORD
  script:
    - python setup.py sdist
    - twine upload --repository-url $NEXUS_REPOSITORY_URL dist/*
  only:
    - tags
  tags: [docker]
```

Task: Find ways to improve code

This is a basic Tic-Tac-Toe implementation, but it can be improved:

```
"""
Task: Find potential improvements in the following code. Name them and suggest an alternative.

Code implements a basic TicTacToe game.
"""

import random


def check(game):
    if '.' not in game:
        return True
    if game[0] == game[1] and game[1] == game[2] and game[0] != '.':
        return True
    if game[3] == game[4] and game[4] == game[5] and game[3] != '.':
        return True
    if game[6] == game[7] and game[7] == game[8] and game[6] != '.':
```

```python
        return True
    if game[0] == game[3] and game[3] == game[6] and game[0] != '.':
        return True
    if game[1] == game[4] and game[4] == game[7] and game[1] != '.':
        return True
    if game[2] == game[5] and game[5] == game[8] and game[2] != '.':
        return True
    if game[0] == game[4] and game[4] == game[8] and game[0] != '.':
        return True
    if game[2] == game[4] and game[4] == game[6] and game[2] != '.':
        return True
    return False


def print_board(board):
    print()
    print(board[0] + board[1] + board[2])
    print(board[3] + board[4] + board[5])
    print(board[6] + board[7] + board[8])


def tic_tac_toe(board, player):
    while True:
        if not check(board):
            if player == 'x':
                pos = int(
                    input("[{}] your move [0-8]? ".format(player))
                )
            else:
                pos = random.randint(0, 8)
            if board[pos] == '.':
                board[pos] = player
                if player == "x":
                    player = "o"
                else:
                    player = "x"
                print_board(board)
        else:
            return


if __name__ == "__main__":
    board = ['.' for _ in range(9)]
```

~~~
    tic_tac_toe(board, "x")

```# Clean Code Continued

## Coding Guidelines

* I remember a time, when coding styles were something special. There was
  Checkstyle for Java (first released in 2001).
* Around the same time PEP8 was created (on 05-Jul-2001).

> PEP stands for Python Enhancement Proposal; The first PEP, PEP1, describes
 ↪  the process.

> A PEP is a design document providing information to the Python community,
 ↪  or
> describing a new feature for Python or its processes or environment.

Over 500 PEP has been suggested since then (PEPs are numbered, although with
 ↪  gaps).

Other notable PEPs are:

* [PEP 20 -- The Zen of Python](https://www.python.org/dev/peps/pep-0020/)
* [PEP 257 -- Docstring
 ↪  conventions](https://www.python.org/dev/peps/pep-0257/)
* [PEP 3000 -- Python 3000](https://www.python.org/dev/peps/pep-3000/)


### PEP 8 -- Style Guide for Python Code

> One of Guido's key insights is that code is read much more often than it is
> written. The guidelines provided here are intended to improve the
 ↪  readability
> of code and make it consistent across the wide spectrum of Python code.

Every rule has exceptions.

> However, **know when to be inconsistent** -- sometimes style guide
> recommendations just aren't applicable. **When in doubt, use your best
> judgment**. Look at other examples and decide what looks best. And don't
> hesitate to ask!

### PEP8 condensed
~~~

~~~
#### Layout

* use 4 spaces (tabs, however, increase accessible e.g. for visually impaired programmers)
* indent consistently (Python 3 disallows mixing the use of tabs and spaces for indentation)

You can go further by using a tool like
[editorconfig](https://editorconfig.org/) to communicate a standard.

* continuation alignment ([examples](https://www.python.org/dev/peps/pep-0008/#indentation))
* maximum of 79 chars per line, and use continuation to break up lines or backslashes (note: I've seen this rule ignored often)
* lines should break before a binary operator ([example](https://www.python.org/dev/peps/pep-0008/#should-a-line-break-before-or-after-a-binary-operator))
* blank lines: 2 around classes and top level functions; one around methods; sparingly inside functions
* code should be written in UTF-8
* imports should be on separate lines
  ([example](https://www.python.org/dev/peps/pep-0008/#imports)), and always on
top of the file; in the best case they follow an order (stdlib, 3rd-party,
local).

> There is a tool called [isort](https://github.com/PyCQA/isort) that allows
> you to sort imports.

```python
$ cat unsorted.py
import re
import csv
import pandas as pd
~~~

Check the ordering.

```
 isort -c unsorted.py
ERROR: ... Snippets/SortImports/unsorted.py
    Imports are incorrectly sorted and/or formatted.
```

Dry run with -d flag:

```
$ isort -d unsorted.py
import csv
import re

import pandas as pd
```

- prefer absolute imports and simple package layouts
- put "module level dunder" names after docstring, before imports (except future special import)

String Quotes

- both single and double quotes are allowed, use consistently

Whitespace

- various considerations around whitespace; examples

Trailing commas

```
FILES = ('setup.cfg',)
```

It would be syntactically correct to remote the parentheses, but they are left for clarity.

In lists, the last value can (and should) have a comma, too:

```
FILES = [
    'setup.cfg',
    'tox.ini',
    ]
```

Comments

> Comments that contradict the code are worse than no comments. Always make a priority of keeping the comments up-to-date when the code changes!

That is both an important and hard rule to follow. You have to think about documentation as something equally important as code. It helps to **re-read** code and fix issue incrementally.

Sidenote: Motivation and Documentation

Armin Ronacher, a long time active member of the Python community remarked that documentation should look good. So good, that you want to write more of it, or make it even clearer. There are a couple of documentation framework that can help with that.

> Comments should be complete sentences. The first word should be capitalized, unless it is an identifier that begins with a lower case letter.

Sidenote: Comments and documentation can be a topic of discussion.

More than once I heard:

> Nobody will use my code, I do not need comments.

True, and often realistic. But is it enough to skip it altogether? Maybe you are working on different project and after two years you come back to old, undocumented code - your code can get foreign (even to yourself) soon.

I think there are reasons to skip e.g. documentation entirely, you want a throwaway prototype or something similar.

- no inline comments, unless specific

```
x = x + 1                 # Increment x
```

Comments can distract, but might add context.

```
x = x + 1                 # Compensate for border
```

Other

PEP8 talks about names, and as they are important, let's move them to a separate section.

Naming Conventions

Let's first pin down a few general prinicples.

We name variables, functions, classes, modules, packages. Good names ease understanding, less good names obstruct, or even mislead. Remember that code is read 90% of the time, so considering sensible names is important.

Reveal your intent

The following code snippet does not reveal its intent.

```
def get_it():
    list1 = []
    for x in the_list:
        if x % 4 == 0:
            list1.append(x)
    return list1
```

- *implicity* of code
- the zen of python states (line 2): explicit is better then implicit

Trying to be explicit is an act of communication.

Distinct names

- you will find fewer of these names in Python, but XYZControllerForEfficientHandlingOfStrings, XYZControllerForEfficientStorageOfStrings are not distinct enough

Meaningful distinctions

It happens that you have more of one thing and you end up with variable names like: a1, a2 and so on.

Typically, there is a better way to write this by grouping similar items in a container like list or dictionary.

```
transforms = [a, b, c]
```

What has been a1 will become a[0] and so on.

Sidenote: Intents

- read own code and other peoples code
- good variable names make comments obsolete
- use constructs with intent

As an example for intent, sometimes you can choose between a list and tuple. A tuple signals immutability to a reader, while functionally using a list or tuple might be equivalent.

You can use a list and check, if an element is already in there. But Python has a built-in `set` data type that conveys this exact meaning.

A program can have an exit code (e.g. important when used in scripts). It is a fine detail, but these exit codes can convey meaning (some programs, e.g. like wget use a range of exit codes that you can quickly lookup, which is helpful for debugging).

Example: Snippets/Unique

Avoid noise

Other languages (e.g. Go) are being explicit about this, although Python has a more flexible import system.

```python
class Product:

    def __init__(self):
        self.product_info = {}
        self.product_data = {}

product = Product()
product.product_info # XXX: too noisy
...
```

Noise slows us down. Imaging you encounter two classes, e.g.:

- Customer
- CustomerObject

Which one do you choose? Every decision we open up to the reader to figure out him or herself can be a potential time sink as the reader needs to establish the context first, by reading code, reading documentation, asking a colleague and so on. Something that should have taken a minute, takes hours or days.

Use pronouncable names

- `modymdhms` is hard to spell out and (without autocomplete) easy to get wrong

Use searchable names

Code is read more often that it is written and finding relevant code is important.

- Rule: The length of a name should correspond to the size of its scope

When using the command line, `grep -r` and `ack` are your friends.

Avoid mental mapping

We see this over and over again: clean code relates to reducing the *cognitive load*.

> But programmers are smart and juggle many things in their head at any point in time, no?

> Yes, they are and do. But clarity is king.

- a name that does not need a (semantic) translation reduces cognitive load

Don't be cute

- since you can use any name, why not spice up names

```python
def make_me_a_sandwich(user):
    """ Grants user admin privileges. """
    ...
```

- do not do it, keep it boring, `set_admin_privileges(user)`.

Use one word per concept

- fetch, retrieve, get - what is the difference?
- you are again making the reader think (which you want, but also do not want)
- if I see method names using fetch, retrieve and get used for similar things, I will start to try to understand what exactly this difference is made of - which takes away time

Other examples:

- controller, manager, driver
- transform, process, modify, …

Use solution domain names

There will usually be a specific technical term, that has

```python
def enqueue_task(task):
    ...

def handle_websockets(conn):
    ...

def dfs(node):
    ...
```

Use problem domain names

When no technical term fits the bill, names from the problem domain should be used.

```
def edge_detect(img):
    ...
```

Naming Conventions according to PEP8

In the context of PEP8.

- aspirational, should be considered, but ok to miss, when code exists that follows a different style

Regarding noise

> The X11 library uses a leading X for all its public functions. In Python, this style is generally deemed unnecessary because attribute and method names are prefixed with an object, and function names are prefixed with a module name.

```
import os

if os.path.exists("filename"):
    pass
```

An exception is `os.stat` which returns (the C equivalent of a) namedtuple (PyStructSequence); here all fields are prefixed by `st_`, e.g. `st_mode`, `st_size` (see: https://git.io/JUbO5).

Names to avoid

Single character variables names:

- `l`, `O`, `I`

Module names should be short

Excluding some files, there are about 800 python files in the Python distribution.

- around 20% of the module names have an underscore in it (see sample)

```
mac_greek.py
text_file.py
import_diagnostics.py
mac_croatian.py
build_scripts.py
popen_fork.py
iso8859_14.py
find_max_nesting.py
iso8859_2.py
asdl_highlight.py
```

Class Names

- should use the `CapWords` convention

Exceptions

- should be written with `CapWords` as classed, but have `Error` appended
- Example: `ClassificationError`

Global variable names

- try to avoid them; the can make reasoning about functions that use them much harder

If you use them on a module level, use the `__all__` mechanism to explicitly name exported names.

Function and variable names

> Function names should be lowercase, with words separated by underscores as necessary to improve readability.

> Variable names follow the same convention as function names.

> mixedCase is allowed only in contexts where that's already the prevailing style (e.g. threading.py), to retain backwards compatibility.

Function and method arguments

> Always use **self** for the first argument to instance methods.

> Always use **cls** for the first argument to class methods.

Instance variables

- use a leading underscore only to for non-public methods and instance variables
- there are not visibility modifiers in Python, so access will still be possible

Constants

- typically `ALL_UPPERCASE`

Design for inheritance

Some ideas to keep in mind in context of object oriented programming.

- start with non-public methods, if unsure; as a public API might mean commitment
- or otherwise make clear that an API is not fixed yet

Attribute access.

> For simple public data attributes, it is best to expose just the attribute name, without complicated accessor/mutator methods.

- keep functional aspect (e.g. via properties) side-effect free
- no computationally expensive operation in a property (the attribute access signals a relatively fast operation)

Try to design classes to be subclasses in a way, that reduces the need to hide data to a minimum. There is a name-mangling rule in Python.

```python
class A:
    def __init__(self):
        self.name = "any"
        self.lang = "python"

class M:
    def __init__(self):
        self.__name = "any"
        self.__lang = "python"

class B(A):
    def hello(self):
        print(self.name)

class C(M):
    def hello(self):
        print(self.__name)

b = B()
c = C()

b.hello()
# c.hello() # AttributeError
```

Private and public interfaces

> To better support introspection, modules should explicitly declare the names in their public API using the `__all__` attribute. Setting `__all__` to an empty list indicates that the module has no public API.

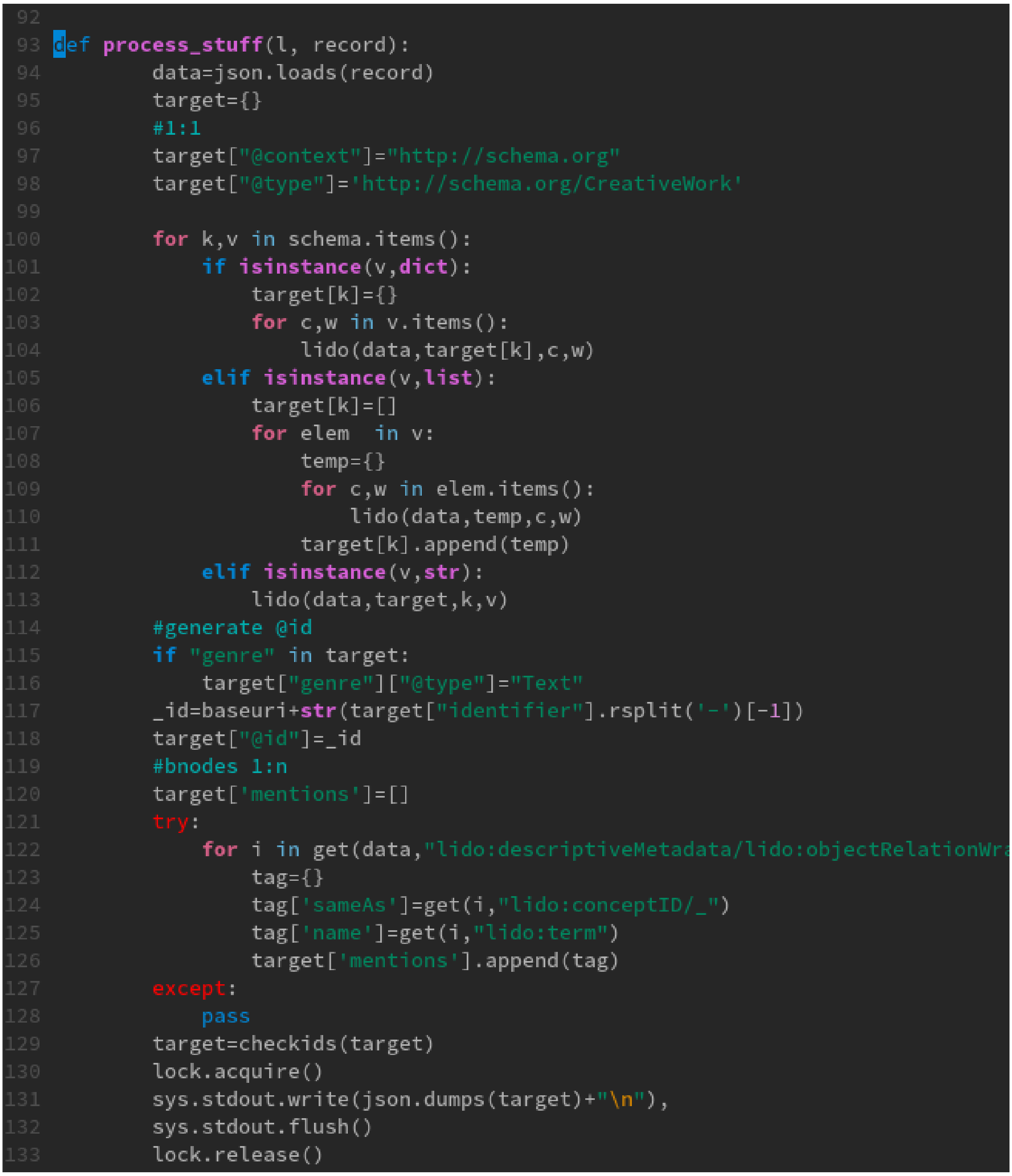
Clean Code rules and principles

Care in small things will add up. Ergonomically, it might be easier to focus on a little improvement at a time.

Some guiding principles:

- write small functions
- use descriptive names
- use boolean flags as little as possible
- minimize side effects
- do one thing
- do not repeat yourself

Sidenote: A Python snippet from the web



```

def process_stuff(l, record):
        data=json.loads(record)
        target={}
        #1:1
        target["@context"]="http://schema.org"
        target["@type"]='http://schema.org/CreativeWork'

        for k,v in schema.items():
            if isinstance(v,dict):
                target[k]={}
                for c,w in v.items():
                    lido(data,target[k],c,w)
            elif isinstance(v,list):
                target[k]=[]
                for elem  in v:
                    temp={}
                    for c,w in elem.items():
                        lido(data,temp,c,w)
                    target[k].append(temp)
            elif isinstance(v,str):
                lido(data,target,k,v)
        #generate @id
        if "genre" in target:
            target["genre"]["@type"]="Text"
        _id=baseuri+str(target["identifier"].rsplit('-')[-1])
        target["@id"]=_id
        #bnodes 1:n
        target['mentions']=[]
        try:
            for i in get(data,"lido:descriptiveMetadata/lido:objectRelationWra
                tag={}
                tag['sameAs']=get(i,"lido:conceptID/_")
                tag['name']=get(i,"lido:term")
                target['mentions'].append(tag)
        except:
            pass
        target=checkids(target)
        lock.acquire()
        sys.stdout.write(json.dumps(target)+"\n"),
        sys.stdout.flush()
        lock.release()
```

- Snippets/Lido

Again, use the etherpad.

> Question: Name a few issue with this code.

You can read the code here as well:

- https://gist.github.com/miku/dce655ebbfb7218760af4c8c60f47629#file-example-py-L93-L133
- https://git.io/JUNMr

SOLID Principles

Principles for design. Managing dependencies (between components) - how change propagates to a system. There can be similar concerns expressed for data (e.g. dependencies of data artifacts).

Single Responsibility Principle (SRP)

- SRP: a class should have one and only one reason to change - reported in Philosophy of Software Design as a typical error (e.g. HTTP request library)

Open/closed principle (OCP)

- you should be able to extend a class's behaviour without modifying; a compositional pattern

Typically done by subclassing a base class.

- we extend the behaviour
- we reuse methods of the superclass
- the superclass is completely unaware of its subclasses

If the superclass changes its behaviour, it will affect the subclasses.

- another way is to extract interfaces and supply different implementations
- an interface is declarative, does not supply implementation and hence subclasses will not be coupled to a specific superclass implementation detail

In Python, explicit interfaces are rarely seen.

- You can define a class to be subclassed and provide no implementation.

Example: Snippets/AbstractClass

The standard library supports the implementation of a number of standard interfaces in the collections.abc module.

Liskov substitution principle (LSP)

- Objects of a superclass shall be replaceable with objects of its subclasses without breaking the application.

Example of a not following this rule: Liskov

Interface Segregation Principle (ISG)

- No client should be forced to depend on method it does not use ()
- keep interfaces small

In Python, we have duck-typing. You can pass any object to a function, as long as it "responds" to a method, it satisfies an *informal* interface.

- Example: Reader

Dependency Inversion Principle (DIP)

- High-level modules should not depend on low-level modules. Both should depend on abstractions (e.g. interfaces).
- Abstractions should not depend on details. Details (concrete implementations) should depend on abstractions.

A typical design approach is bottom-up: Write lower level components first, then build abstractions on top of them, directly. This can lead to coupling, as a lower level module might not easily changed.

By introducing an abstraction, a user and provider of functionality can be decoupled.

- Example: DependencyInversion

Note: Dependency Injection is a debated topic in Python. Why is IoC / DI not common in Python?.

Quoting James Shore:

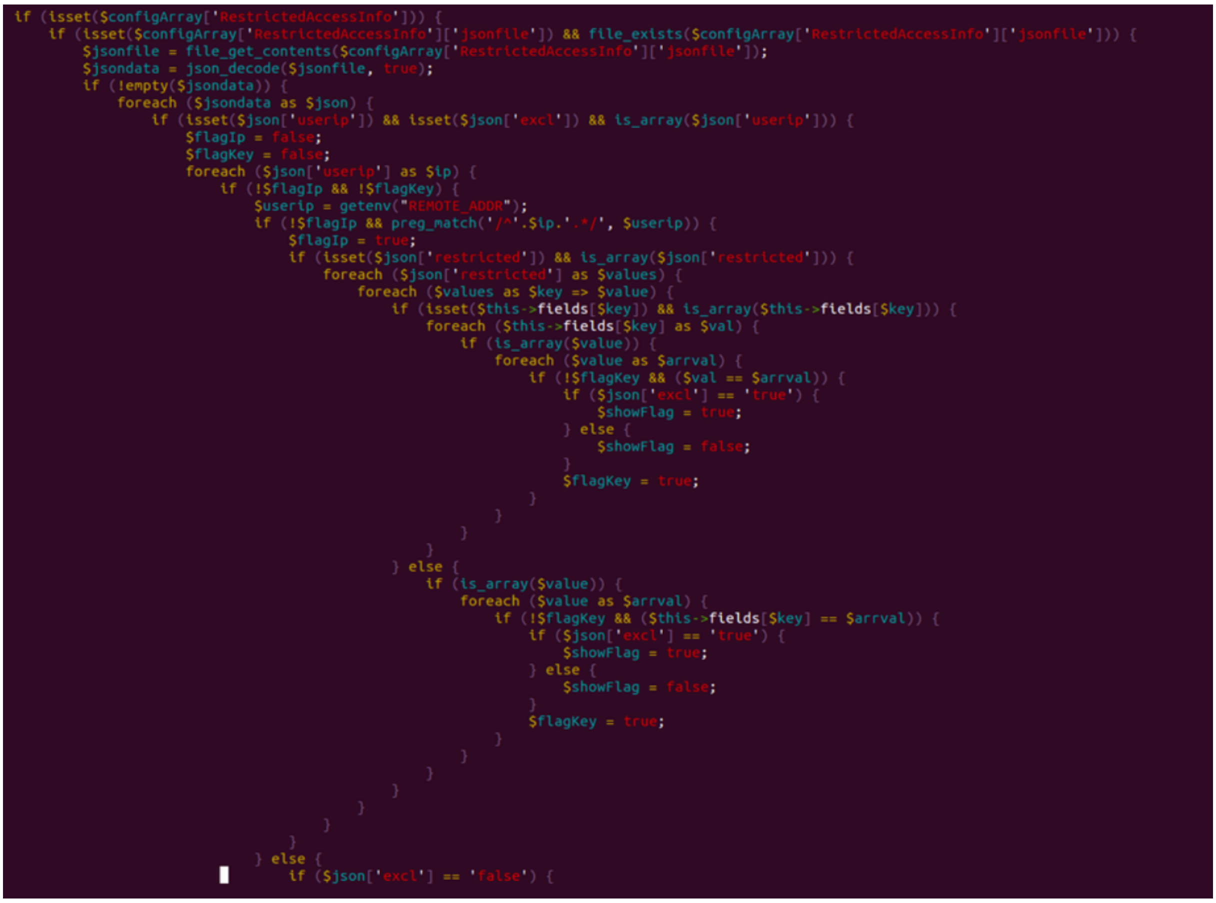
> "Dependency Injection" is a 25-dollar term for a 5-cent concept. […] Dependency injection means giving an object its instance variables.

Generic rules

- KISS (keep it simple, solid), aka "flintstoning"
- DRY (don't repeat yourself)

- YAGNI (you ain't gonna need it)
- Composition over inheritance (example: logging module in standard library)
- Readability counts (Line seven of Zen of Python)
- The rule of three
- Principle of least surprise

A small, but effective tweak.



```
if (isset($configArray['RestrictedAccessInfo'])) {
    if (isset($configArray['RestrictedAccessInfo']['jsonfile']) && file_exists($configArray['RestrictedAccessInfo']['jsonfile'])) {
        $jsonfile = file_get_contents($configArray['RestrictedAccessInfo']['jsonfile']);
        $jsondata = json_decode($jsonfile, true);
        if (!empty($jsondata)) {
            foreach ($jsondata as $json) {
                if (isset($json['userip']) && isset($json['excl']) && is_array($json['userip'])) {
                    $flagIp = false;
                    $flagKey = false;
                    foreach ($json['userip'] as $ip) {
                        if (!$flagIp && !$flagKey) {
                            $userip = getenv("REMOTE_ADDR");
                            if (!$flagIp && preg_match('/^'.$ip.'.*/', $userip)) {
                                $flagIp = true;
                                if (isset($json['restricted']) && is_array($json['restricted'])) {
                                    foreach ($json['restricted'] as $values) {
                                        foreach ($values as $key => $value) {
                                            if (isset($this->fields[$key]) && is_array($this->fields[$key])) {
                                                foreach ($this->fields[$key] as $val) {
                                                    if (is_array($value)) {
                                                        foreach ($value as $arrval) {
                                                            if (!$flagKey && ($val == $arrval)) {
                                                                if ($json['excl'] == 'true') {
                                                                    $showFlag = true;
                                                                } else {
                                                                    $showFlag = false;
                                                                }
                                                                $flagKey = true;
                                                            }
                                                        }
                                                    }
                                                }
                                            } else {
                                                if (is_array($value)) {
                                                    foreach ($value as $arrval) {
                                                        if (!$flagKey && ($this->fields[$key] == $arrval)) {
                                                            if ($json['excl'] == 'true') {
                                                                $showFlag = true;
                                                            } else {
                                                                $showFlag = false;
                                                            }
                                                            $flagKey = true;
                                                        }
                                                    }
                                                }
                                            }
                                        }
                                    }
                                }
                            } else {
                                if ($json['excl'] == 'false') {
```

The rule spelled out:

> Let the happy path flow down the left hand edge.

If necessary invert conditions to keep reduce indent.

```python
if json_obj is not None:
    authors = json_obj.get("author")
    if authors is not None:
        for author in authors:
            orcid = self.om.normalise(author.get("ORCID"))
            if orcid is not None:
                result.add(orcid)
```

Task: Apply the "happy path" rule to the snippet above.

- https://github.com/opencitations/index/commit/09af4a174c0a6dbcf4a838550b5ad558fc3dcee6

Patterns and anti-patterns in Python

Patterns and anti-patterns.

Avoid global

A global variable can potentially be altered from many places and can complicate code comprehension.

- avoid the `global` keyword

Sidenote: On a higher level, the essay/paper "Out of the tar pit" (2006) talks about common problems in software construction.

One key observation is that state, and keeping track of state.

> The biggest problem in the development and maintenance of large-scale software systems is complexity — large systems are hard to understand. We believe that the major contributor to this complexity in many systems is the handling of state and the burden that this adds when trying to analyse and reason about the system.

Avoid mutable default values

A source of bugs is the following snippet:

```
def fun(a=1, b=[]):
    b.append("x")
    print(b)


fun()
fun()
```

The alternative is to use None as a default:

```
def fun(a=1, b=None):
    if b is None:
        b = []
    b.append("x")
    print(b)
```

EAFP

Python prefers the style: easier to ask for forgiveness than permission, or EAFP for short.

Example:

```
data = {
    "a": 1,
    "b": 2,
}

# Works, LBYL style (https://docs.python.org/3/glossary.html#term-lbyl)
if data.has_key("a"):
    v = data["a"]
else:
    do_something_else()

# Better, following EAFP (https://docs.python.org/3/glossary.html#term-eafp)
try:
    v = data["a"]
except KeyError:
    do_something_else()
```

Classes vs functions

- OOD and OOP emphasize classes (and some languages require them)
- Python is a “multi-paradigm” langauge

- Talk by Jack Dietrich: “Stop writing classes” (reducing hundreds of lines to a few dozens)

Test automation and test-driven development

- a school of programming favors a test first approach (or TDD)
- the basic idea: write a failing test first, then write code to make it pass (and only to make it pass)

Example: Snippets/TestDriven

Refactoring tools

- typically supported by IDEs, such as PyCharm
- rename, invert boolean, …

Code metrics

- tokei; sloccount
- pylint

Detecting fragile code

- cyclomatic complexity

Balanced Toolset

More tools:

- pyflakes
- mypy and type hints - Example: Snippets/Mypy

```
$ mypy Snippets/Mypy/hints.py
Success: no issues found in 1 source file
```

- pycodestyle (formerly pep8)

Example output:

```
$ pycodestyle --first siskin
siskin/__init__.py:43:80: E501 line too long (80 > 79 characters)
siskin/conversions.py:136:24: E741 ambiguous variable name 'l'
siskin/mab.py:168:12: E713 test for membership should be 'not in'
siskin/mappings.py:82:1: E265 block comment should start with '# '
siskin/test_arguments.py:52:27: E711 comparison to None should be 'if cond
 ↪  is None:'
siskin/test_utils.py:140:26: E712 comparison to True should be 'if cond is
 ↪  True:' or 'if cond:'
siskin/utils.py:96:9: E731 do not assign a lambda expression, use a def
siskin/utils.py:566:29: W605 invalid escape sequence '\d'
siskin/assets/161/161_marcbinary.py:27:5: E722 do not use bare 'except'
siskin/assets/101/101_marcbinary.py:60:15: W291 trailing whitespace
siskin/assets/183/183_marcxml_sru.py:100:72: E262 inline comment should
 ↪  start with '# '
```

Enforcing code styles.

- black
- yapf

The latter can be configured.

```
$ cat .style.yapf
[style]

based_on_style = pep8
split_before_logical_operator = true
column_limit = 160
```

Elements of agile programming

Agile programming tries to take on a different perspective on software development, shifting emphasis.

- Individuals and interactions over processes and tools
- Working software over comprehensive documentation
- Customer collaboration over contract negotiation
- Responding to change over following a plan

Value feedback and everything that allows you to collect feedback more easily.

Sidenote: A way to get to feedback.

Working on a plugin project for a application, that was slowly loading. Every invocation (e.g. manual test) required to wait about ten seconds and would involve a couple more manual steps. Doable, but annoying.

Solution: Factor out the bare minimum to execute the code (e.g. the plugin loader) plus add some preloading.

Result: feedback time went from a minute to two seconds, development speed and motivation did not decline.

Learning from successful open source projects

- reading popular source repositories
- reading the standard library

Open source has various pragmatic aspects:

- time constrained development
- a wide range of contributions (developers of various levels, code, documentation, bug reports, pull requests, …)

Deconstructing complex code

- no single approach
- start or extend documentation
- extract (common) functions
- extract shared code into an independent library
- if they do not exist, write tests for functions
- try to find existing libraries that implement functionality

---

What do you think?

> Question: Which approach or technique of clean code do you find easily applicable? Which one not?

A few tips for Software Design

Inspired by:

- Twelve quick tips for software design. PLoS Comput Biol 18(2): e1009809. https://doi.org/10.1371/journal.pcbi.10

Design after the fact

> Many designers explain the design of their software by recapitulating its history [7,8]. This is sometimes called challenge and response: The only way to understand why some- thing works the way it does is to understand the problems that existed at the time it was written and the tools that were available then.

Relates to comments in code that describe the circumstance (and not what is written).

- approach: write first, design, refactor

Design for people's cognitive capacity

- humans have a short term memory limit
- How many details do I need to keep in my head as I am reading a particular piece of code?

Design in coherent levels

- functions should be short, shallow and single purpose
- something that only takes up one slot in short term memory

You can ask: Between how many levels of detail do I need to jump while reading this code?

```python
def main():
    config = buildConfiguration(sys.argv)
    state = initializeState(config)
    while config.currentTime < config.haltTime:
        updateState(config, state)
    report(config, state)
```

The `while` condition could be taken "a level up", e.g. like:

```
...
while stillEvolving(config, state):
   updateState(config, state)
   ...
```

Design for Evolution

> More realistically, a change in one place should only require a small number of changes in a few predictable places.

For example `stillEvolving` could be changed internally (to adapt), while client code stays the same.

Two main ways:

- information hiding (interface, api and implementation)
- loose coupling (e.g. *command line*)

Group related information together

What is easier to read?

```
def enclose (x0, y0, z0, x1, y1, z1, nearness):
    ...
```

Or:

```
def enclose (p0, p1, nearness):
    ...
```

Design for delivery

- take care of the build process
- maybe a common way to build the project (e.g. Makefiles) ## The pytest project
- python has unittest is standard library, classic framework (inspired by JUnit)
- setUp, tearDown, assertTrue, assertEquals, assertRaises, …

The basic notions are similar:

- fixture
- test case
- test suite
- test runner
- one goal of pytest was to be a bit more pythonic (with unittest coming fro JUnit)
- helpful messages

Basics

- pytest detects tests by name prefix, e.g. `test_*` functions and methods
- grouping in a class possible
- only a single `assert`

Calling pytest with filename, directory or via name filter `-k` to select specific files.

```
$ pytest test_fixture.py
$ pytest -k fix
```

Marks

- setting metadata on functions
- a list of builtin marks can be found here: marks

For example, you can mark a test function with skipif to skip under certain conditions; or xfail to expect a failed test.

Fixtures

- pytest approach to fixtures is interesting, as it is mostly name based

If we run this, we do not get any output.

```
def test_hello(tmpdir):
    print(tmpdir)
```

The test would pass, but not print anything on this successful test.

```
platform linux -- Python 3.7.8, pytest-6.1.1, py-1.9.0, pluggy-0.13.1
rootdir: /home/tir/code/miku/cleancodepython/Snippets/TestingBasic
collected 1 item

test_fixture.py .                                                [100%]
```

We need to pass `-s` shortcut to see the output, as pytest offers various capture method.

```
  --capture=method     per-test capturing method: one of fd|sys|no|tee-
sys.
  -s                    shortcut for --capture=no.
```

Default:

> During test execution any output sent to stdout and stderr is captured. If a test or a setup method fails its according captured output will usually be shown along with the failure traceback.

The output can be captured on a filesystem (fd 0 and 1) level (e.g. when calling external commands) or on `sys.write` level. The `tee-sys` captures and passes through output, like the tee (T) command.

- Example: Snippets/Testing, `test_ls.py`

There are more builtin fixtures:

- https://docs.pytest.org/en/stable/builtin.html

Examples are: caching values, capturing logging messages, recording warnings

Fixture: monkeypatch

> monkeypatch can be used to patch functions dependent on the user to always return a specific value.

- Example: Snippets/Testing, `test_ssh.py`

Custom fixture

Fixtures can provide various test dependencies. They are a form of dependency injection.

You can include these in your testfiles or in `conftest.py` to be shared by multiple tests.

A fixture can be valid in different scopes:

> Fixtures requiring network access depend on connectivity and are usually time-expensive to create. Extending the previous example, we can add a scope="module" parameter to the @pytest.fixture invocation to cause the decorated smtp_connection fixture function to only be invoked once per test module (the default is to invoke once per test function).

> Possible values for scope are: function, class, module, package or session.

Initialization goes from session to function.

A fixture can handle both setup and teardown, when using `yield` at the point where execution should continue in the test.

Examples:

- `test_fixture_custom.py`
- `test_fixture_autouse.py`
- `test_fixture_yield.py`

Other plugins

- common data directory for test files: pytest-datadir or pytest-datafiles

Table Driven Tests

Not a new idea, but popularized a bit more by Go:

- https://github.com/golang/go/wiki/TableDrivenTests
- boil down cases to rows in a table
- can be also pushed out (e.g. to CSV file or similar)

Code coverage

Coverage measures the ratio of tested lines of code and lines of code. 100% coverage does not mean bug free.

Automated tool:

- https://coverage.readthedocs.io/en/coverage-5.3/

You can run it standalone:

```
$ coverage run -m pytest -v
```

This will generate an sqlite3 database, be default `.coverage`. Generate a report:

```
$ coverage report -i gluish/*
Name                      Stmts   Miss  Cover
-----------------------------------------
gluish/__init__.py            8      0   100%
gluish/common.py            117     59    50%
gluish/format.py             70     30    57%
gluish/intervals.py          27     15    44%
gluish/parameter.py           5      0   100%
gluish/task.py               77     55    29%
gluish/utils.py              54     30    44%
-----------------------------------------
TOTAL                       358    189    47%
```

Or install a pytest plugin for coverage.

```
$ pip install pytest-cov
```

Run alongside tests:

```
$ pytest --cov=gluish -v gluish/*
```

Various outputs are available, e.g. HTML.

Other testing helpers

requests is a popular HTTP library, responses is a great addition to test HTTP interactions.

```
@pytest.fixture
def mocked_responses():
    with responses.RequestsMock() as rsps:
        yield rsps

def test_api(mocked_responses):
    mocked_responses.add(
        responses.GET, 'http://twitter.com/api/1/foobar',
        body='{}', status=200,
        content_type='application/json')
    resp = requests.get('http://twitter.com/api/1/foobar')
    assert resp.status_code == 200
```

Other Plugins

- 1402 projects with "pytest" in their name (not all plugins, presumably)

A few interesting ones may be:

- SeleniumBase - for web application testing
- pytest-clarity - for improved diffs

Extra Tools

There are different testing helpers for various circumstances.

Mutation testing:

> https://github.com/mutpy/mutpy

Tries to modify code slightly.

> Mutation testing (or Mutation analysis or Program mutation) evaluates the quality of software tests. Mutation testing involves modifying a program's source code or byte code in small ways. A test suite that does not detect and reject the mutated code is considered defective.

- limited pytest support (but test runner seems ok)

Example: [Snippets/MutPy]

Refactoring

Why change code at all:

- feature
- bugfix
- better design
- optimization

Business Case

- better code is easier to maintain
- you can spend a day or a week or a month on refactoring
- there has to be a business case, too
    - cannot spend a year on code that will be phased out in two years
    - cannot spend a year improving design while features are waiting
- compromise: reserve one day just for retroactive improvements
    - improvement can take longer, but try to make a tiny progress in each session
- if your business is growing, then business case for more change it there
    - product will exist ten years from now

Technical Debt

A probably useful metaphor for understanding accumulated issues in projects.

- deadlines
- no tests
- insufficient documentation
- change of requirements

Optimize for learning

- try to postpone decisions
- the later you have to decide, the more informed your decision will be

API design

- once your API is clear, and you have a test harness, refactoring becomes a breeze

> Exercise: Please refactor the following piece of code. We want to make it a bit more performant […] - one example with another without tests

Examples of great API designs:

- scikit-learn
- keras (beat tensorflow)

What is a change?

Examples:

- ☒ adding a function
- ☒ removing a function
- ☒ changing a function

Why not change?

- hard, not sure if something breaks
- touches many parts

Before you refactor

Maybe this can save some time: https://github.com/97-things/97-things-every-programmer-should-know/blob/master/en/thing_06/README.md

- the best approach for restructuring starts by taking stock of the existing codebase and the tests written against that code.
- avoid the temptation to rewrite everything
- many incremental changes are better than one massive change

> side note: git add/reset -p is made for that

- after each iteration, it is important to ensure that the existing tests pass.
- personal preferences and ego shouldn't get in the way
- new technology is insufficient reason to refactor
- remember that humans make mistakes

I would add:

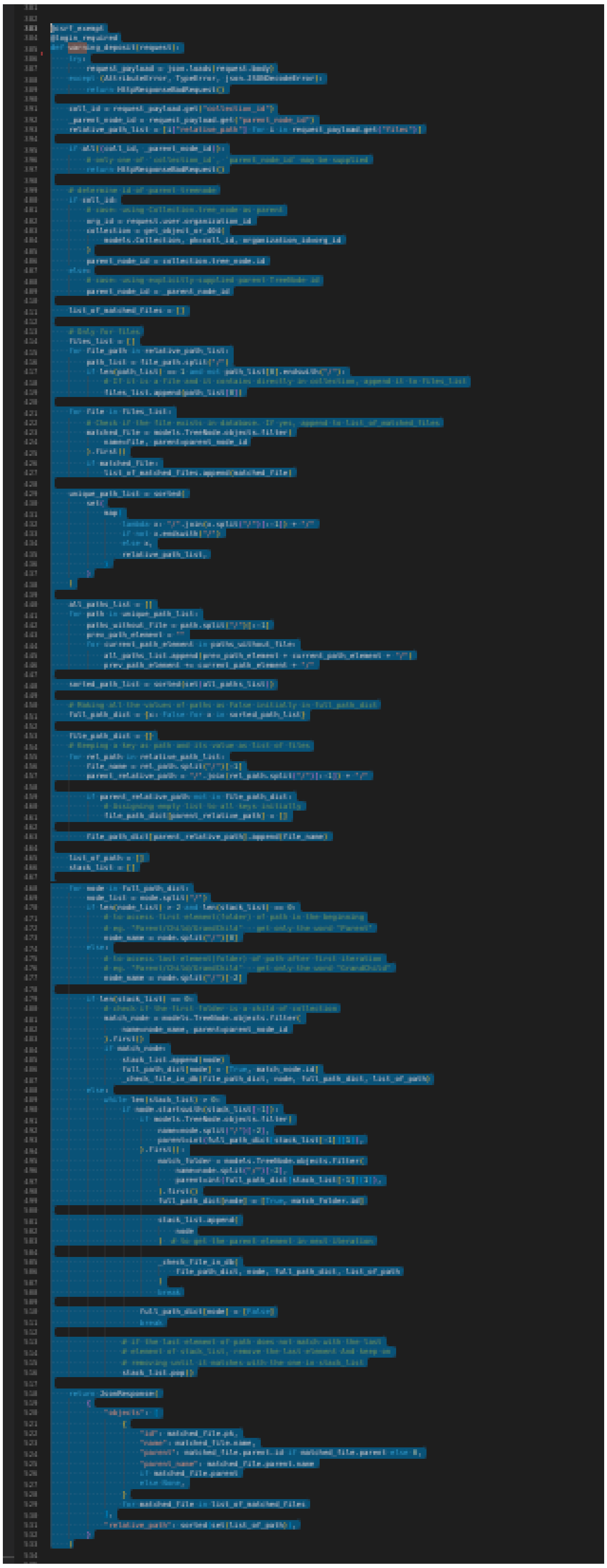
- co-ordinate with team (and maybe author) before refactoring

A few problems

Code bloat

- long methods
- large classes

- primitive obsession
- long parameter list



```python
@csrf_exempt
@login_required
def warning_deposit(request):
    try:
        request_payload = json.loads(request.body)
    except (AttributeError, TypeError, json.JSONDecodeError):
        return HttpResponseBadRequest()

    coll_id = request_payload.get("collection_id")
    _parent_node_id = request_payload.get("parent_node_id")
    relative_path_list = [i["relative_path"] for i in request_payload.get("files")]

    if all((coll_id, _parent_node_id)):
        # only one of `collection_id`, `parent_node_id` may be supplied
        return HttpResponseBadRequest()

    # determine id of parent treenode
    if coll_id:
        # case: using Collection.tree_node as parent
        org_id = request.user.organization_id
        collection = get_object_or_404(
            models.Collection, pk=coll_id, organization__id=org_id
        )
        parent_node_id = collection.tree_node.id
    else:
        # case: using explicitly supplied parent TreeNode id
        parent_node_id = _parent_node_id

    list_of_matched_files = []

    # Only for files
    files_list = []
    for file_path in relative_path_list:
        path_list = file_path.split("/")
        if len(path_list) == 1 and not path_list[0].endswith("/"):
            # If it is a file and it contains directly in collection, append it to files_list
            files_list.append(path_list[0])

    for file in files_list:
        # Check if the file exists in database. If yes, append to list_of_matched_files
        matched_file = models.TreeNode.objects.filter(
            name=file, parent=parent_node_id
        ).first()
        if matched_file:
            list_of_matched_files.append(matched_file)

    unique_path_list = sorted(
        set(
            map(
                lambda x: "/".join(x.split("/")[:-1]) + "/"
                if not x.endswith("/")
                else x,
                relative_path_list,
            )
        )
    )

    all_paths_list = []
    for path in unique_path_list:
        paths_without_file = path.split("/")[:-1]
        prev_path_element = ""
        for current_path_element in paths_without_file:
            all_paths_list.append(prev_path_element + current_path_element + "/")
            prev_path_element += current_path_element + "/"

    sorted_path_list = sorted(set(all_paths_list))

    # Making all the values of paths as False initially in full_path_dict
    full_path_dict = {x: False for x in sorted_path_list}

    file_path_dict = {}
    # Keeping a key as path and its value as list of files
    for rel_path in relative_path_list:
        file_name = rel_path.split("/")[-1]
        parent_relative_path = "/".join(rel_path.split("/")[:-1]) + "/"

        if parent_relative_path not in file_path_dict:
            # Assigning empty list to all keys initially
            file_path_dict[parent_relative_path] = []

        file_path_dict[parent_relative_path].append(file_name)

    list_of_path = []
    stack_list = []

    for node in full_path_dict:
        node_list = node.split("/")
        if len(node_list) = 2 and len(stack_list) == 0:
            # to access first element(folder) of path in the beginning
            # eg. "Parent/Child/GrandChild" -- get only the word "Parent"
            node_name = node.split("/")[0]
        else:
            # to access last element(folder) of path after first iteration
            # eg. "Parent/Child/GrandChild" -- get only the word "GrandChild"
            node_name = node.split("/")[-2]

        if len(stack_list) == 0:
            # check if the first folder is a child of collection
            match_node = models.TreeNode.objects.filter(
                name=node_name, parent=parent_node_id
            ).first()
            if match_node:
                stack_list.append(node)
                full_path_dict[node] = [True, match_node.id]
                _check_file_in_db(file_path_dict, node, full_path_dict, list_of_path)
        else:
            while len(stack_list) > 0:
                if node.startswith(stack_list[-1]):
                    if models.TreeNode.objects.filter(
                        name=node.split("/")[-2],
                        parent=int(full_path_dict[stack_list[-1]][1]),
                    ).first():
                        match_folder = models.TreeNode.objects.filter(
                            name=node.split("/")[-2],
                            parent=int(full_path_dict[stack_list[-1]][1]),
                        ).first()
                        full_path_dict[node] = [True, match_folder.id]

                        stack_list.append(
                            node
                        )  # to get the parent element in next iteration

                        _check_file_in_db(
                            file_path_dict, node, full_path_dict, list_of_path
                        )
                        break

                    full_path_dict[node] = [False]
                    break

                # if the last element of path does not match with the last
                # element of stack_list, remove the last element and keep on
                # removing until it matches with the one in stack_list
                stack_list.pop()

    return JsonResponse(
        {
            "objects": [
                {
                    "id": matched_file.pk,
                    "name": matched_file.name,
                    "parent": matched_file.parent.id if matched_file.parent else 0,
                    "parent_name": matched_file.parent.name
                    if matched_file.parent
                    else None,
                }
                for matched_file in list_of_matched_files
            ],
            "relative_path": sorted(set(list_of_path)),
        }
    )
```

Change preventers

- divergent change (changes across many different methods)

Dispensables

- comments
- duplicate code
- dead code
- speculative generality

Couples

- feature envy (object access data of another object more than its own)
- middle man (a thin class, mostly delegating to another)
- message chains (like `a.b.c.d()`)

A few techniques

Improve methods

- extract methods
- inline
- move
- rename

Remove dead code

- identify unused code
- mostly after implementation of larger features

Decompose Conditional

- make conditionals easier to read

```
if date.before(SUMMER_START) or date.after(SUMMER_END):
    charge = quantity * winterRate + winterServiceCharge
else:
    charge = quantity * summerRate

# better

if isSummer(date):
    charge = summerCharge(quantity)
else:
    charge = winterCharge(quantity)
```

- remove control flags (use break or continue instead)
- quick poll: anyone used `for ... else` in Python?

Introduce Null Object

```
if customer is None:
    plan = BillingPlan.basic()
else:
    plan = customer.getPlan()

# better

class NullCustomer(Customer):

    def isNull(self):
        return True

    def getPlan(self):
        return self.NullPlan()

    # Some other NULL functionality.

# Replace null values with Null-object.
customer = order.customer or NullCustomer()

# Use Null-object as if it's normal subclass.
plan = customer.getPlan()
```

Parameterize Function

- after two or more special cases, a parameter may be approriate

```
def run_once():

def run_twice():

# better

def run(n=1):
```

Introduce Parameter Object

- group related values into an own object

Hide Delegate

> If a caller uses object A to get to object B and the called explicity call object B - then maybe delegate calls to B from A - so the caller only deals with a single object.q

Encapsulate Collection

- instead of exposing a collection, add methods and encapsulate details

Some notes from Refactoring to Patterns

- overengineering happens

> because programmer do not want to be stuck in a bad design

> But over time the power of patterns led me to lose sight of simpler ways to write code.

Ex: strategy vs. a simple conditional

Then: Underengineered software. Can cause pain as well.

- everything talks to everything else (e.g. no layers, little abstraction, …)

At some point you consider a total rewrite.

> TDD and continuous refactor

Two XP practices.

- TDD: Ask, Respond, Refine; Test case, code, rewrite case, repeat

Or, Kent Back:

- red, green, refactor

Task: Code with some issues

```python
"""
The following code has some issues, find them and try to correct them.

Note: This class does not have tests (no need to add any for the moment).
However, real refactoring should be done against tested code.
"""

import json

class Processor:

    def __init__(self, data=None, lookup=None):
        self.data = data

    def load(self):
        self.loaded = json.loads(self.data)

    def filter_by_a(self, records):
        result = []
        for record in records:
            if 'a' in record:
                for value in result:
                    if 'a' in value:
                        break
                else:
                    result.append(record)
        return result

    def filter_by_b(self, records):
        result = []
        for record in records:
            if 'b' in record:
                for value in result:
                    if 'b' in value:
```

~~~
                        break
                else:
                    result.append(record)
        return result



data = '[{"a": 1}, {"b": 2}, {"c": 3}, {"a": 4}, {"b": 5}]'
processor = Processor(data=data)
processor.load()
for record in self.filter_by_a(self.loaded):
    print(record)
```# Documentation

Some notes on comments and documentation.

## README driven development

* describe what is happening first, without writing any code
* overview, usage examples, caveats

## Make docs look good

* make something you want to read
    * choose a suitable format (sometimes a README is enough)
    * choose a suitable tool (e.g. mkdocs, sphinx, ...)
    * if you comment code, you get almost free documentation
    * choose a nice template
* document functions, classes, modules if it is not totally obvious
* never repeat what the code already says
* add specific learnings, if possible

> You may wonder what kind of comments you can find in production code (e.g.
 ↪  you
> may learn details about operating system distributions)

## Docstrings for quick examples

Example: [holiday.py](https://github.com/pandas-
 ↪  dev/pandas/blob/ddf2541df866e89150210d41c22e45eb2cf83e91/pandas/tseries/holiday.py#L
 ↪  L213)

```python
~~~

```
class Holiday:
    """
    Class that defines a holiday with start/end dates and rules
    for observance.
    """

    def __init__(
        self,
        name,
        year=None,
        month=None,
        day=None,
        offset=None,
        observance=None,
        start_date=None,
        end_date=None,
        days_of_week=None,
    ) -> None:
        """
        Parameters
        ----------
        name : str
            Name of the holiday , defaults to class name
        offset : array of pandas.tseries.offsets or
                class from pandas.tseries.offsets
            computes offset from date
        observance: function
            computes when holiday is given a pandas Timestamp
        days_of_week:
            provide a tuple of days e.g  (0,1,2,3,) for Monday Through
 ↪  Thursday
            Monday=0,..,Sunday=6
        Examples
        --------
        >>> from dateutil.relativedelta import MO
        >>> USMemorialDay = pd.tseries.holiday.Holiday(
        ...     "Memorial Day", month=5, day=31,
 ↪  offset=pd.DateOffset(weekday=MO(-1))
        ... )
        >>> USMemorialDay
        Holiday: Memorial Day (month=5, day=31, offset=<DateOffset:
 ↪  weekday=MO(-1)>)
        >>> USLaborDay = pd.tseries.holiday.Holiday(
        ...     "Labor Day", month=9, day=1,
 ↪  offset=pd.DateOffset(weekday=MO(1))
        ... )
        >>> USLaborDay
        Holiday: Labor Day (month=9, day=1, offset=<DateOffset:
 ↪  weekday=MO(+1)>)
        >>> July3rd = pd.tseries.holiday.Holiday("July 3rd", month=7, day=3)
        >>> July3rd
        Holiday: July 3rd (month=7, day=3, )
        >>> NewYears = pd.tseries.holiday.Holiday(
        ...     "New Years Day", month=1,  day=1,
        ...      observance=pd.tseries.holiday.nearest_workday
        ... )
        >>> NewYears  # doctest: +SKIP
        Holiday: New Years Day (
            month=1, day=1, observance=<function nearest_workday at
 ↪  0x66545e9bc440>
        )
        >>> July3rd = pd.tseries.holiday.Holiday(
        ...     "July 3rd", month=7, day=3,
        ...     days_of_week=(0, 1, 2, 3)
        ... )
        >>> July3rd
        Holiday: July 3rd (month=7, day=3, )
        """
```

Comments

- the best code needs no comments
- be specific and record part of the "situation", maybe a decision process
- better no comment than an outdated comment
- reread code to make sure comments still make sense
- mark todo items (maybe even with names): `TODO(martin)` - this can be found in almost any project - helps to pick up a development thread at a later point in time# A few more Python Patterns and Anti-Patterns

Everything that pylint (or other linter) can be an opportunity to improve code.

- http://pylint-messages.wikidot.com/all-codes

Pairwise iteration with zip

- using builtin zip

```
vs = [1, 2, 3]
letters = ["A", "B", "C"]

for index in range(len(vs)):
    print(vs[index], letters[index])
```

With `zip` we can write the loop as a parallel iteration:

```
vs = [1, 2, 3]
letters = ["A", "B", "C"]

for v, letter in zip(vs, letters):
    print(v, letter)
```

Test Object Identity with `is`

We have both == and `is` is Python.

- `is` compares reference
- == compares values (can be any custom procedure)

No need to write:

```
if x == True:
    ...
```

Better:

```
if x is True:
    ...
```

Or just:

```
if x:
    ...
```

It can improve readability when dealing with collections and we want to check for the existence, we pull in `len` - to be explicit.

```
vs = []
if vs:
    ....
```

Alternative:

```
vs = []
...

if len(vs) == 0:
    ...
```

Using `type` to compare types

- use `isinstance` instead, as it will cater for inheritance

Using index variables in for loops

Use the builtin enumerate:

```
seq = list('abc')
for i, v in enumerate(seq):
    print(i, v)
```

Use tuple unpacking

```
def gcd(a, b):
    while b != 0:
        tmp = b
        b = a % b
        a = tmp
    return a
```

Tuple unpacking allows for:

```
def gcd(a, b):
    while b != 0:
        a, b = b, a % b
    return a
```

Star-imports

In general, you should not need star imports:

```
from module import *
```

What is exported can be controlled with the `__all__` special variable.

Plain open files

We can open and close files manually:

```
f = open("file.txt")
f.close()
```

But context managers are encouraged:

```
with open("file.txt") as f:
    pass
```

Varied return types

Rare, but it this is used it can be confusing - even though dynamic typing allows for any return type.

```
def f(x=0):
    if x > 0:
        return x
    else:
        return False
```

Design Patterns

A look into design patterns and their applications Python.

Favor object composition over class inheritance

- you can extend classes along multiple "axes", which leads to "class proliferation"
- standard library "logging" is an example of "composition over inheritance"

Logging

With inheritance only, you could wind up with:

- Logger
- StdoutLogger
- StderrLogger
- FilteredStdoutLogger
- …

Various ways to adapt:

- **Adaptor** pattern, using a conventional interface, e.g. the "write" method and wrap all output modalities in a new class supplying this function, adapting to the needs of the logger.
- **Bridge**, similar to Adaptor, but using a custom abstraction, e.g. a message that works slightly higher in the hierarchy (e.g. passing a message, versus "write")

> "Adapter makes things work after they're designed; Bridge makes them work before they are. [GoF, p219]"

- **Decorator** pattern

If a filter wraps a logger with the same method name, e.g. `log`, we can stack them.

```python
class Filter:
    def __init__(self, pattern, logger):
        self.pattern = pattern
        self.logger = logger

    def log(self, message):
        if pattern in message:
            self.logger.log(message)

log1 = SomeLogger("app.log")
log2 = Filter("debug", log1)
log3 = Filter("todo", log2)
...
```

The way the standard library implements logging is by separating loggers, formatters, handlers.

> Handler objects are responsible for dispatching the appropriate log messages (based on the log messages' severity) to the handler's specified destination.

- streams, files

Actually, more the docs list more than 10 implementations, like `TimeRotatingFileHandler` and `HTTPHandler`.

> Formatter objects configure the final order, structure, and contents of the log message. Unlike the base logging.Handler class, application code may instantiate formatter classes, although you could likely subclass the formatter if your application needs special behavior.

Putting these things together:

```
import logging

# create logger
logger = logging.getLogger('simple_example')
logger.setLevel(logging.DEBUG)

# create console handler and set level to debug
ch = logging.StreamHandler()
ch.setLevel(logging.DEBUG)

# create formatter
formatter = logging.Formatter('%(asctime)s - %(name)s - %(levelname)s -
 ↪  %(message)s')

# add formatter to ch
ch.setFormatter(formatter)

# add ch to logger
logger.addHandler(ch)

# 'application' code
logger.debug('debug message')
logger.info('info message')
logger.warning('warn message')
logger.error('error message')
logger.critical('critical message')
```

MVC

- model view controller, separation of concerns

Often used in frameworks with UI elements.

- web frameworks
- GUI frameworks, although Tkinter seems to have a more tighter coupling

In web framworks the separation goes along:

- database abstraction and queries (M)
- mostly logic-less HTML templates (V)
- handing of the request-response cycle (C)

In desktop toolkits, you will have some **Observer** pattern implemented.

For example in a classic (Java) example, the tabular data model (`TableModel`) can inform other components about change via `addTableModelListener`, propagating events.

A test for true MVC design:

> Is the program functional even without the view? Or the controller?

Global objects

- similar to singletons

Often used for constants, defined on module level and exported.

Special cases, e.g. *dunder* constants, like `__version__`.

A few builtin dunder names:

- `__file__` (the current file)
- `__name__` (the name of the module, e.g. `__main__` when invoked from the command line)

Abstract Factory

Factories are classes that build objects. Not really needed in Python.

> But Python has the concept of callables, which typically allow to pass in the class itself.

Python has first class functions, which are callable. Methods are callable, and classes are, too, if they implement `__call__`.

There are alternatives:

- a simple function
- a method on a class

- a generator with some state

```
class Switch:
    def __init__(self):
        self.on = False
    def __call__(self):
        print("switch is {}".format("on" if self.on else "off"))
        self.on = bool(1 - self.on)


switch = Switch()
switch()
switch()
```

For specifying required functionality, create an abstract class by returning `NotImplementedError` on the methods that subclasses need to provide.

Singleton pattern

Examples: Snippets/Singleton

- overwriting __new__
- not that pronounced either, use global object instead

Iterator pattern

There is concept of an iterator in Python (in iterable), iterator.

- `iter` has a dual role; it turns a sequence into an iterator or allows to use a callable to create a sequence

Example application, reading a file in blocks:

```
from functools import partial
with open('mydata.db', 'rb') as f:
    for block in iter(partial(f.read, 64), b''):
        process_block(block)
```

> Return a new *partial* object which when called will behave like func called with the positional arguments args and keyword arguments keywords.

Facade

- providing a simplified interface while delegating work to one or more other classes

Wrap Up

Design patterns exists, but some of the original patterns are less prevalent as Python constructs exist to (partially) address the problems.

Pythonic Code

The zen of Python says:

> There should be one– and preferably only one –obvious way to do it.

There are often different approaches possible.

EAFP

- easier to ask for forgiveness than permission

```
try:
    data = float(value)
except ValueError:
    print("not a float")
```

Indexed iteration

- Python has the builtin `enumerate` for that

```
i = 0
for v in values:
    i += 1
    print(i, v)
```

The pythonic way to write this would be:

```
for i, v in enumerate(values):
    print(i, v)
```

> Tour: Magic Methods

- notebooks/Magic_Methods_Part_1.ipynb
- notebooks/Magic_Methods_Part_2.ipynb

Decorators

- decorators allow to factor out certain cross-cutting concerns
- they are used as an integration tool (e.g. joining routes of a web application with handlers)
- they work, because python has first class functions

Examples:

```
from flask import Flask
app = Flask(__name__)

@app.route('/')
def hello_world():
    return 'Hello, World!'
```

- more examples: https://wiki.python.org/moin/PythonDecoratorLibrary

Writing a decorator

A decorator is syntactic sugar for:

```
@decorator
def some_function():
    pass

some_function = decorator(some_function)
```

The main idea is to return a function, that wraps the original function.

- Snippets/Decorator

```
def deco(f):
    def inner(*args, **kwargs):
        print("[deco] calling {}".format(f.__name__))
        result = f(*args, **kwargs)
        print("[deco] exited {}".format(f.__name__))
        return result
    return inner

@deco
def hello(name="world"):
    print("hello " + name)

hello()
```

Protocols

One strength of Python is its ability to blend the core language with custom code. Your object can behave similarly to a sequence or dictionary.

The key are special methods, or "dunder" methods. More information can be found in the data model docs, special method names.

> A class can implement certain operations that are invoked by special syntax (such as arithmetic operations or subscripting and slicing) by defining methods with special names. This is Python's approach to operator overloading, allowing classes to define their own behavior with respect to language operators.

Protocol: str and repr

- `__str__`
- `__repr__`

Protocol: length

- `__len__`

Protocol: item access

- `__getitem__`
- `__setitem__`
- `__delitem__`

```
class Sample:

    def __getitem__(self, key):
        return "42"

s = Sample()
print(s["hi"])
```

Protocol: iteration

> Python supports a concept of iteration over containers. This is implemented using two distinct methods; these are used to allow user-defined classes to support iteration.

- `__iter__`
- `__next__`

The `StopIteration` exception serves as a sentinel value.

Protocol: Equality

Beside a few other methods for object comparison, we can define:

- `__eq__` to customize equality checks

Example: A case insensitive strings class

```
class Str(str):

    def __eq__(self, other):
        if not isinstance(other, str):
            raise TypeError
        return self.lower() == other.lower()

a = "Hello"
b = "hello"

print(a == b)
print(Str(a) == Str(b))
```

The functools.total_ordering decorator will supply the rest of the comparison operators, if one or more comparison ordering method is defined.

Protocol: context manager

- resource setup and teardown
- typically used with files

Example for sqlite.

```
class sqlitedb():
    """
    Simple cursor context manager for sqlite3 databases. Commits everything
 ↪  at exit.
        with sqlitedb('/tmp/test.db') as cursor:
            query = cursor.execute('SELECT * FROM items')
            result = query.fetchall()
    """
    def __init__(self, path, timeout=5.0, detect_types=0):
        self.path = path
        self.conn = None
        self.cursor = None
        self.timeout = timeout
        self.detect_types = detect_types

    def __enter__(self):
        self.conn = sqlite3.connect(self.path, timeout=self.timeout,
         ↪  detect_types=self.detect_types)
        self.conn.text_factory = str
        self.cursor = self.conn.cursor()
        return self.cursor

    def __exit__(self, exc_class, exc, traceback):
        self.conn.commit()
        self.conn.close()
```

Task: Context manager

Benchmarking context manager and decorator example.

1. Implement a context manager that can be used to track the execution time of a piece of code.

It could be used, e.g. like this:

```
with Timer() as timer:
    result = some_function()
print(timer.elapsed_s) # prints out elapsed seconds
```

2. Implement a decorator called `@timed` which can be added to functions to measure their execution time. This decorator can use the context manager defined.

~~~~
@timed
def sum_numbers(n=10000):
    return sum(i for i in range(n))

sum_numbers(1_000)
sum_numbers(1_000_000)
sum_numbers(100_000_000)
```## Generators

> A function which returns a generator iterator. It looks like a normal
 ↪  function
> except that it contains yield expressions for producing a series of values
> usable in a for-loop or that can be retrieved one at a time with the next()
> function.

> Each yield temporarily suspends processing, remembering the location
 ↪  execution
> state (including local variables and pending try-statements). When the
> generator iterator resumes, it picks up where it left off (in contrast to
> functions which start fresh on every invocation).

Analogously to list comprehensions, you have generator expressions.

You can implement generators by implementing a class that implements two
 ↪  functions:

* `__iter__`
* `__next__`

Example: [Snippets/Generator](Snippets/Generator)

```python
class Gen:

    def __iter__(self):
        return self

    def __next__(self):
        return "42"
~~~~

```
gen = Gen()
print(next(gen))
print(next(gen))
```

It gets more interesting, when you have state that is kept between invocations.

```
class Gen:

    def __init__(self):
        self.i = 0

    def __iter__(self):
        return self

    def __next__(self):
        self.i += 1
        if self.i < 4:
            return self.i
        else:
            raise StopIteration

gen = Gen()
for i in gen:
    print(i)
```

Finally, the `yield` keyword allows to write a generator without a class.

```
def gen():
    i = 0
    while i < 3:
        i += 1
        yield i


for i in gen():
    print(i)
```

Differences:

- less code
- we do not need to implement the protocol ourselves

> As a short exercise: Try to implement a generator that behaves like the builtin `enumerate` - used for indexed iteration.

Generator use cases

- os.walk
- processing pipelines

A number example:

```
numbers = (i for i in range(1, 10))
squared = (i*i for i in numbers)
filtered = (i for i in squared if i % 7 == 0)

for v in filtered:
    print(v)
```

Example image processing pipeline:

- iterates over a list of files
- resizes the images
- pads each image with a border

```
imgs = (imageio.imread(f) for f in filenames)
imgs = (resize_image(img, width=width) for img in imgs)
imgs = (pad_image(img, border=border, bordercolor=bordercolor) for img in
 ↪  imgs)
```

After these three lines, nothing will happen because generators are lazy and nothing has been evaluated so far.

You can imaging doing something with a single image and then write it out.

Advantages:

- pipeline is extendable
- memory efficient
- pythonic (other languages do need more workarounds)

Task

Write a generator that mimics the builtin range without using `range`.

- use a class based approach and

- a generator function approach

Example usage would be like:

~~~
for i in Range(0, 10, 2):
    print(i)

# 0
# 2
# 4
# 6
# 8
```## Decorators

* decorators allow to factor out certain cross-cutting concerns
* they are used as an integration tool (e.g. joining routes of a web
 ↪  application with handlers)
* they work, because python has first class functions

Examples:

```python
from flask import Flask
app = Flask(__name__)

@app.route('/')
def hello_world():
    return 'Hello, World!'
~~~

- more examples: https://wiki.python.org/moin/PythonDecoratorLibrary

Writing a decorator

A decorator is syntactic sugar for:

```
@decorator
def some_function():
    pass

some_function = decorator(some_function)
```

The main idea is to return a function, that wraps the original function.

- Snippets/Decorator

```
def deco(f):
    def inner(*args, **kwargs):
        print("[deco] calling {}".format(f.__name__))
        result = f(*args, **kwargs)
        print("[deco] exited {}".format(f.__name__))
        return result
    return inner

@deco
def hello(name="world"):
    print("hello " + name)

hello()
```

Functools Helper

- we can wrap the inner function (with a decorator) to keep name and docstring

```
from functools import wraps


def my_decorator(f):
    @wraps(f)
    def wrapper(*args, **kwds):
        print('Calling decorated function')
        return f(*args, **kwds)
    return wrapper

@my_decorator
def example():
    """Docstring"""
    print('Called example function')

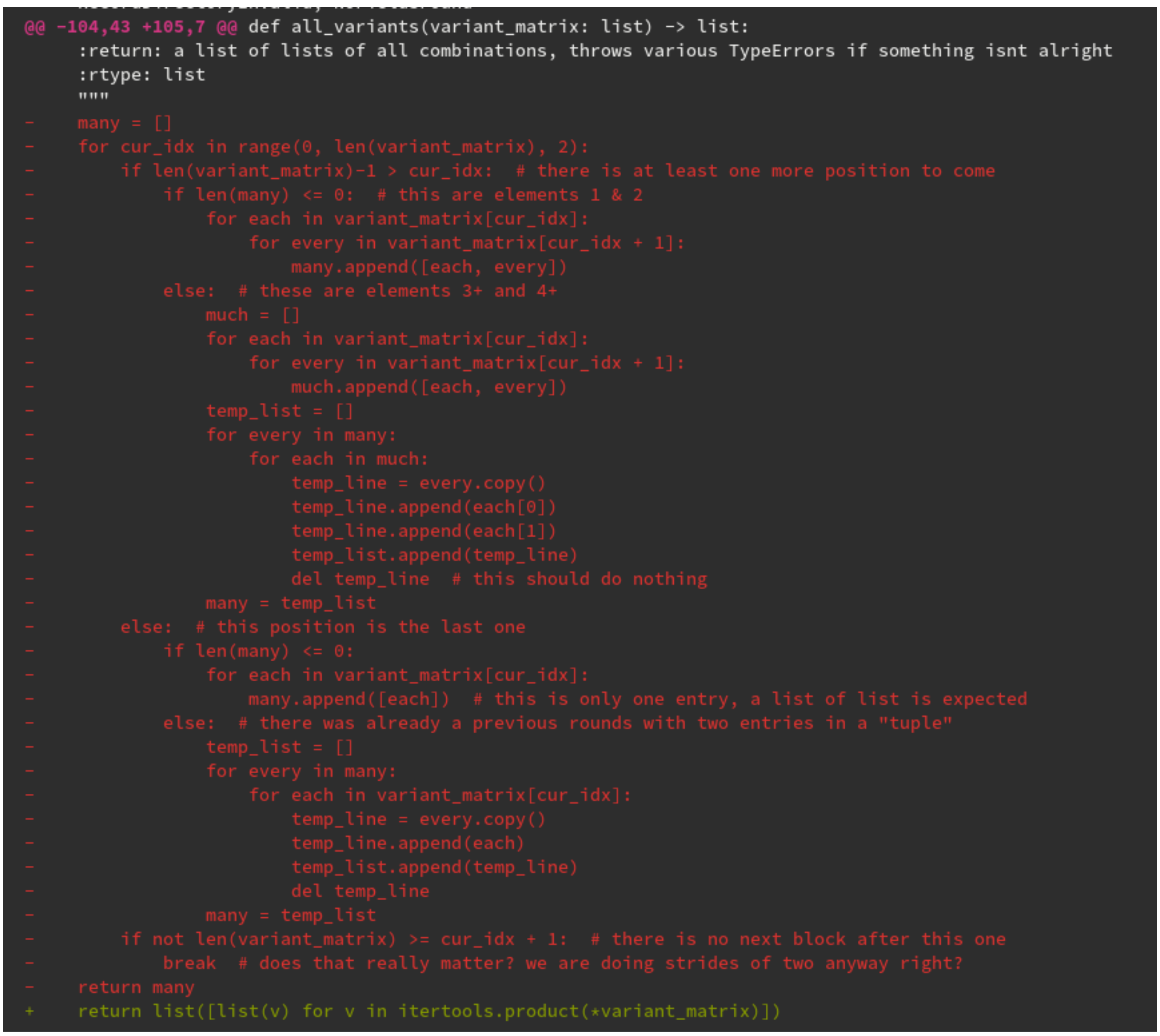
example()

print(example.__name__)
print(example.__doc__)
```

Itertools

> The module standardizes a core set of fast, memory efficient tools that are useful by themselves or in combination.

As the docs say:



```
@@ -104,43 +105,7 @@ def all_variants(variant_matrix: list) -> list:
     :return: a list of lists of all combinations, throws various TypeErrors if something isnt alright
     :rtype: list
     """
-    many = []
-    for cur_idx in range(0, len(variant_matrix), 2):
-        if len(variant_matrix)-1 > cur_idx:  # there is at least one more position to come
-            if len(many) <= 0:  # this are elements 1 & 2
-                for each in variant_matrix[cur_idx]:
-                    for every in variant_matrix[cur_idx + 1]:
-                        many.append([each, every])
-            else:  # these are elements 3+ and 4+
-                much = []
-                for each in variant_matrix[cur_idx]:
-                    for every in variant_matrix[cur_idx + 1]:
-                        much.append([each, every])
-                temp_list = []
-                for every in many:
-                    for each in much:
-                        temp_line = every.copy()
-                        temp_line.append(each[0])
-                        temp_line.append(each[1])
-                        temp_list.append(temp_line)
-                        del temp_line  # this should do nothing
-                many = temp_list
-        else:  # this position is the last one
-            if len(many) <= 0:
-                for each in variant_matrix[cur_idx]:
-                    many.append([each])  # this is only one entry, a list of list is expected
-            else:  # there was already a previous rounds with two entries in a "tuple"
-                temp_list = []
-                for every in many:
-                    for each in variant_matrix[cur_idx]:
-                        temp_line = every.copy()
-                        temp_line.append(each)
-                        temp_list.append(temp_line)
-                        del temp_line
-                many = temp_list
-        if not len(variant_matrix) >= cur_idx + 1:  # there is no next block after this one
-            break  # does that really matter? we are doing strides of two anyway right?
-    return many
+    return list([list(v) for v in itertools.product(*variant_matrix)])
```

Various types of functions:

- Infinite iterators
- Iterators terminating on the shortest input sequence
- Combinatoric iterators

Task

Implement a truth table printer for an arbitrary boolean expression. Something that looks like this. In the best case, the formula can be any valid boolean formula.

You may find itertools useful, and maybe also str.maketrans as well as eval.

Examples:

```
not (A and B)
-------------
not (0 and 0) | 1
not (0 and 1) | 1
not (1 and 0) | 1
not (1 and 1) | 0
```

Or:

```
not ((not (A and B)) and (not (A and B)))
-----------------------------------------
not ((not (0 and 0)) and (not (0 and 0))) | 0
not ((not (0 and 1)) and (not (0 and 1))) | 0
not ((not (1 and 0)) and (not (1 and 0))) | 0
not ((not (1 and 1)) and (not (1 and 1))) | 1
```

Online-Tools: https://web.stanford.edu/class/cs103/tools/truth-table-tool/

Collections

The collections module offers a variety of utility types.

Default dictionary

The standard library has many special purpose utilities.

```
freq = {}
```

```python
for char in ("a", "b", "c", "b", "c", "c"):
    if char in freq:
        freq[char] += 1
    else:
        freq[char] = 0
```

A more compact way to write this would be a default dictionary.

```python
import collections

freq = collections.defaultdict(int)
for char in ("a", "b", "c", "b", "c", "c"):
    freq[char] += 1
```

There is also a `collections.Counter` which is a default dictionary with int values and a helper method: `most_common`.

Records with namedtuples

If you have structured information, like a record, consider using a `namedtuple` or a dataclass.

- tuple
- namedtuple
- dataclass (supplies basic special methods like `str`, allows default values, metadata and more)

```python
from dataclasses import dataclass

@dataclass()
class Point:
     x: int
     y: int


p = Point(2, 3)

print(p)
```

- anytime you use a tuple and you are repeatedly accessing by index, you can look into a namedtuple
- simpler than a DataClass
- a factory function, builds a subclass of `tuple`
- interchangable with tuples

Example: [Snippets/Namedtuple]

Typed named tuples

Example: [Snippets/TypedNamedTuple]

Related: Data Classes

Data Classes allow to group values, type annotate them.

```
from dataclasses import dataclass

@dataclass(init=True, repr=True, eq=True, order=True, unsafe_hash=False,
 ↪  frozen=False)
class Point:
     x: int
     y: int


p = Point(2, 3)

print(p)
```

- Examples: Snippets/Dataclass

Map for working with missing keys: defaultdict

- defaultdict provides for a facility to set a dictionaries default value type (e.g. a list)

```
>>> dd = collections.defaultdict(list)
>>> dd["ids"].append(1)
>>> dd["ids"].append(2)
>>> print(dd)
defaultdict(<class 'list'>, {'ids': [1, 2]})
```

Counter

- a dictionary subclsas that helps to keep track of counting
- came out of a typical use case

```
>>> c = collections.Counter()
>>> c["a"] += 2
>>> c["b"] += 3
>>> c.most_common()
[('b', 3), ('a', 2)]
```

Task: A case for collections

Write a short program that given a string, e.g. like this

```
s = """
From the Python Website: Python is a high-level, general-purpose programming
language. Its design philosophy emphasizes code readability with the use of
significant indentation.
"""

# ...
```

[…] collects basic metrics over the text:

- count how often each word (as is, no need to normalize) appears
- collect long words (e.g. 11 chars or longer)

It can output the following:

- top 3 most common words
- a random sample (e.g. of 3) of the longest words

~~~~
the 2
Python 2
From 1

long words: ['readability', 'high-level,', 'indentation.']
```# Functools

> The functools module is for higher-order functions: functions that act on or retur

Example: caches.

```python
@cache
~~~~

```
def factorial(n):
    return n * factorial(n-1) if n else 1
```

Also: `lru_cache`

Functools contains a helper for decorators as well, namely functools.wraps.# Slots

> **slots** has a mixed reputation in the Python community. On the one hand, they are considered to be popular. Lots of people like using them. Others say that they are badly understood, tricky to get right, and don't have much of an effect unless there are many instances of objects that use them. – https://wiki.python.org/moin/UsingSlots

Example: Snippets/Slots

- we can save a bit memory, as `__dict__` will not be created

Without slots, we can assign create new attributes on the class. Slots limit this.

Summary

> Using **slots** is straightforward. They are a simple, efficient, and safe alternative to Python's default method of data access. The only known exception is when another object requires access to the **dict** attribute. # Exception Handling

Some rules:

- catch specific exceptions
- you can react to different failures differently with multiple except block
- try to recover gracefully, if sensible
- it is ok to no handle exceptions and just pass them up to the caller # Short Tweaks

Some examples for discussion.

Conditions

```
condition == "=" or condition == ">" or condition == ">=":
```

Literals

```
new_mapping = {}
for key in mapping:
    new_mapping[str(key).lower()] = mapping[key]
mapping = new_mapping
```

Bool Bool

```
if self._DESCRI is not None:
    return True
else:
    return False
```

Code Organization and Continous Integration (CI)

Structuring Python Projects

- python code can be a short single file (with standard library only)
- modules and packages

Code Walkthrough: Package miniretry

The miniretry package is a minimal package and demonstrates a project skeleton and the code, publish and install cycle.

- Repository
- PyPI

Virtual environments

- motivation: separate projects and their dependencies

> a self-contained directory tree that contains a Python installation for a particular version of Python, plus a number of additional packages

Basic Usage

```
$ apt-get install python3-venv
$ python3 -m venv example
$ tree example
$ tree -d example -I "__pycache__"
example
├── bin
├── include
├── lib
```

```
│   └── python3.6
│       └── site-packages
│           ├── pip
│           │   ├── commands
│           │   ├── compat
│           │   ├── models
│           │   ├── operations
│           │   ├── req
│           │   ├── utils
│           │   ├── vcs
│           │   └── _vendor
│           ├── pip-9.0.1.dist-info
│           ├── pkg_resources
│           │   ├── extern
│           │   └── _vendor
│           │       └── packaging
│           ├── pkg_resources-0.0.0.dist-info
│           ├── setuptools
│           │   ├── command
│           │   ├── extern
│           │   └── _vendor
│           │       └── packaging
│           └── setuptools-39.0.1.dist-info
├── lib64 -> lib
└── share
    └── python-wheels

29 directories
```

Activation:

```
$ source example/bin/activate
(example) $
$ which python
[...]/example/bin/python
```

Deactivate:

```
(example) $ deactivate
$
```

Virtualenv Helper Scripts

- virtualenvwrapper is a convenience layer

It needs to be source in the shell startup script, which make a few scripts available, like `mkvirtualenv`, `rmvirtualenv` or `workon` to switch between environment.:

Using Conda

- docs

```
$ conda create --name myenv
Collecting package metadata (current_repodata.json): done
Solving environment: done

## Package Plan ##

  environment location: /home/tir/anaconda3/envs/myenv



Proceed ([y]/n)? y

Preparing transaction: done
Verifying transaction: done
Executing transaction: done
#
# To activate this environment, use
#
#     $ conda activate myenv
#
# To deactivate an active environment, use
#
#     $ conda deactivate
```

Collaboration with git

- the branch-review-merge workflow

A few intermediate aspects of git:

- gitbits

Working with hooks

- commitlint

- check lint results before committing, reject commit if source code got worse (e.g. require 7/10 or 8/10)
- static check, e.g. via mypy, again, reject commits on failures

Git and gitlab CI

- gitlab is an open source git repository hosting and CI platfrom
- many CI as a service solutions are available
- automation potential around testing and deployment

Example scenario

A python library, that is tested on every commit and deployed on every tag. A local PyPI conform mirror (e.g. via Nexus OSS), which supports a variety of build artifacts.

- controlled by a version-controlled file, e.g. `gitlab-ci.yml`

```
image: python:3.8.5-slim-buster

stages:
  - test
  - deploy

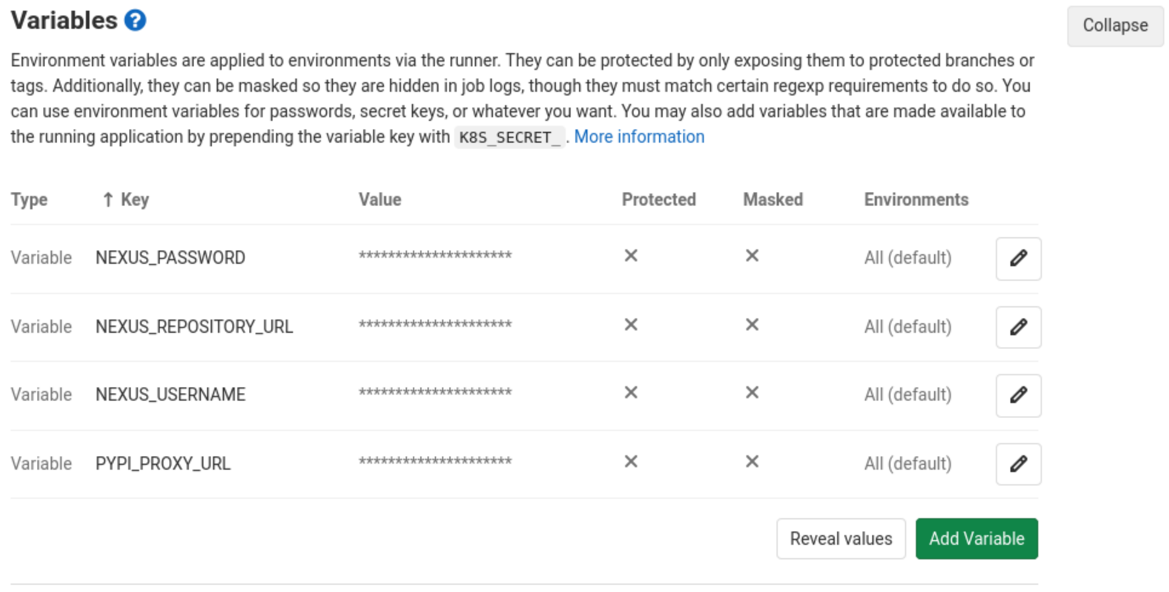
before_script:
    - pip install --upgrade pip
    - pip install pytest twine

tests:
  stage: test
  script:
    - pip install backports.csv # try installing this from pypi, nexus may not like the [.]
    - python setup.py develop --index-url $PYPI_PROXY_URL # faster, less load for pypi
    - pytest
  tags: [docker]
  except:
    - tags

upload_to_nexus:
  stage: deploy
```

```
variables:
  TWINE_USERNAME: $NEXUS_USERNAME
  TWINE_PASSWORD: $NEXUS_PASSWORD
script:
  - python setup.py sdist
  - twine upload --repository-url $NEXUS_REPOSITORY_URL dist/*
only:
  - tags
tags: [docker]
```

You can handle credentials in the web interface (settings differ across platforms).



Variables

Environment variables are applied to environments via the runner. They can be protected by only exposing them to protected branches or tags. Additionally, they can be masked so they are hidden in job logs, though they must match certain regexp requirements to do so. You can use environment variables for passwords, secret keys, or whatever you want. You may also add variables that are made available to the running application by prepending the variable key with `K8S_SECRET_`. More information

Type	↑ Key	Value	Protected	Masked	Environments
Variable	NEXUS_PASSWORD	********************	✕	✕	All (default)
Variable	NEXUS_REPOSITORY_URL	********************	✕	✕	All (default)
Variable	NEXUS_USERNAME	********************	✕	✕	All (default)
Variable	PYPI_PROXY_URL	********************	✕	✕	All (default)

Packaging Python Applications

- See: Packaging

Deployment options

- upload to PyPI
- installing the package
- versioning
- automate artifact creation (see: gitlab example)

Elements of CI: test, build, static code analysis

- CI tools, as service or self-hosted
- Basic gitlab tooling

Tools

- imports: isort (maybe done by your IDE already)
- code style: black, yapf (editor: format on save)
- readability and static analysis: pylint, prospector, pylava
- repository: tokei, sloccount, git of theseus

The yapf tool

- yet another python formatter, developed by google

> In essence, the algorithm takes the code and reformats it to the best formatting that conforms to the style guide, even if the original code didn't violate the style guide. The idea is also similar to the 'gofmt' tool for the Go programming language: end all holy wars about formatting - if the whole codebase of a project is simply piped through YAPF whenever modifications are made, the style remains consistent throughout the project and there's no point arguing about style in every code review.

The reference to the Go ecosystem is interesting.

- Go started with a single style guide and this approach has found its ways into other languages in the past years.
- While this seems like a small thing to do, it really takes away lots of debate, while at the same time improving readability.
- use yapf with your editor

Running it as pre-commit hook or as part of regular code maintenance:

```
$ yapf --parallel --in-place --recurse mypackage
```

The pylint tool

> The Python community has formalized somerecommended programming styles to help everyone write code in a common, agreed-upon style that makes the mostsense for shared code. This style is captured in PEP 8, the "Style Guide for Python Code". Pylint can be a quick andeasy way of seeing if your code has captured the essence of PEP 8 and is thereforefriendlyto other potential users

List of messages:

- http://pylint-messages.wikidot.com/all-codes

It is possible to ignore particular messages with special comments.

```
# pylint: disable=F0401,C0111,W0232,E1101,R0904,E1103,C0301
```

Configurable via `.pylintrc` file.

The pylint tool emits a single score between 0 and 10, rating the code.

```
$ pylint project
...

-----------------------------------
Your code has been rated at 9.37/10
```

Meta analysers

The prospector tool includes a cyclomatic complexity measure (McCabe, 1976).

Example output:

```
$ prospector
project/example/some_file.py
  Line: 102
    pylint: redefined-builtin / Redefining built-in 'all' (col 37)
  Line: 163
   pylint: unbalanced-tuple-unpacking / Possible unbalanced tuple unpacking with se
  Line: 181
    pylint: redefined-builtin / Redefining built-in 'id' (col 4)
  Line: 187
```

```
    mccabe: MC0001 / Loop 187 is too complex (29)
  Line: 212
    pylint: redefined-builtin / Redefining built-in 'format' (col 4)
  Line: 215
    pep8: W605 / invalid escape sequence '\.' (col 26)
    pep8: W605 / invalid escape sequence '\s' (col 28)
    pep8: W605 / invalid escape sequence '\d' (col 30)
    pep8: W605 / invalid escape sequence '\s' (col 33)
    pep8: W605 / invalid escape sequence '\s' (col 37)
    pep8: W605 / invalid escape sequence '\d' (col 40)
  Line: 219
```

The pylava does similar things with a different, yet overlapping set of tools. The default output is a bit more compact.

```
siskin/sources/vkfilmff.py:103:80: E501 line too long (101 > 79 characters) [pycode
siskin/database.py:28:1: W0611 'logging' imported but unused [pyflakes]
siskin/database.py:32:1: W0611 'six.moves.urllib.parse' imported but unused [pyfla
siskin/database.py:38:80: E501 line too long (84 > 79 characters) [pycodestyle]
siskin/database.py:52:80: E501 line too long (100 > 79 characters) [pycodestyle]
```

The tokei tool

There are a lot of source code line counters, but I found tokei to be particularly fast.

- https://github.com/XAMPPRocky/tokei/releases/

```
===============================================================================
 Language         Files       Lines       Code    Comments     Blanks
===============================================================================
 Autoconf             8        2652       2038         154        460
 Batch                3           8          5           2          1
 C Header            16        2540       1429         708        403
 CSS                  1          69         69           0          0
 Dockerfile           1          47         21          19          7
 JSON                 3         132        118           0         14
 Makefile             1          27         19           0          8
 Pan                  2          75         74           1          0
 Python            1104      443745      349100      25715       68930
 ReStructuredText     140       72137       50795         0       21342
 Shell               16         932         609        134         189
 SVG                 13         613         607          5           1
 Plain Text           6         140           0        130          10
 TOML                 1          32          29          2           1
 YAML                22         978         837         59          82
---------------------------------------------------------------------
----------
 HTML               109       12786       12084         55         647
 |- CSS              10         593         327          2         264
 |- JavaScript         5         185        146         19          20
 (Total)                      13564       12557         76         931
---------------------------------------------------------------------
----------
 Jupyter Notebooks      1          0          0          0           0
 |- Markdown          1         237           1        184          52
 |- Python            1         210         189          7          14
 (Total)                        447         190        191          66
---------------------------------------------------------------------
----------
 Markdown            18        1739           0       1271         468
 |- Python            1          40          36          0           4
 (Total)                       1779          36       1271         472
================================================================================
 Total             1465      539917      418533      28467       92917
================================================================================
```

Task: If you have not already, install pylint or prospector and run it against your codebase and get an overview of issues. The output might be noisy, but are there things, that would be easily changed?

—-# Code Quality

Assess how much code it there in the first place

- tokei

```
================================================================================
 Language          Files      Lines        Code    Comments     Blanks
================================================================================
 Autoconf              1          7           6           0          1
 CSS                  11        322         241          29         52
 INI                   1        145         129           8          8
 JavaScript           17       5871        5043         285        543
 Makefile              1        177         143           6         28
 Python              254      61008       45068        5111      10829
 ReStructuredText     15       3165        2323           0        842
 Shell                 4        104          83           6         15
 SVG                   2        794         794           0          0
 TOML                  3         64          46           7         11
 XML                   1          9           8           0          1
 YAML                  2         45          37           3          5
----------------------------------------------------------------------
----------
 HTML                  7        457         401          19         37
 |- CSS                2         76          54          11         11
 |- JavaScript         2        415         404           5          6
 (Total)                        948         859          35         54
================================================================================
 Total               319      72168       54322        5474      12372
================================================================================
```

Linting and Code checks

- pylint

```
$ pylint --list-msgs
```

Includes security issues like `forgotten-debug-statement` and the like.

Another (meta) static code analysis tool is prospector.

```
$ pip install prospector[with_mypy,with_bandit]
```

Or just with everything:

```
$ pip install prospector[with_everything]
```

Example running against a Python OSS project with about 60K SLOC (spotify/luigi):

```
$ prospector

...

Check Information
=================
         Started: 2022-09-06 20:37:04.522971
        Finished: 2022-09-06 20:37:49.662702
      Time Taken: 45.14 seconds
       Formatter: grouped
      Profiles: default, no_doc_warnings, no_test_warnings, strictness_medium, str
      Strictness: None
  Libraries Used:
     Tools Run: dodgy, mccabe, profile-validator, pycodestyle, pyflakes, pylint
  Messages Found: 1399
```

It comes with a set of profiles:

- https://github.com/PyCQA/prospector/tree/master/prospector/profiles/profiles

For example a strictness_veryhigh

```
# This will enable almost every single warning
allow-shorthand: false

ignore-patterns:
  - (^|/)\..+

pylint:
  disable:
    - fixme
    - bad-continuation

  options:
    max-locals: 15
    max-returns: 6
    max-branches: 12
    max-statements: 50
    max-parents: 7
    max-attributes: 7
    min-public-methods: 2
    max-public-methods: 20
    max-module-lines: 1000
    max-line-length: 79

mccabe:
  options:
    max-complexity: 10

pycodestyle:
  options:
    max-line-length: 79
    single-line-if-stmt: n

pyroma:
  disable:
    - PYR19
    - PYR16

pydocstyle:
  disable:
    - D000
```

Security Audit: bandit

> Bandit is a tool designed to find common security issues in Python code. To do this, Bandit processes each file, builds an AST from it, and runs appropriate plugins against the AST nodes.

```
$ bandit -r luigi

...

Code scanned:
        Total lines of code: 21186
        Total lines skipped (#nosec): 0

Run metrics:
        Total issues (by severity):
                Undefined: 0
                Low: 122
                Medium: 34
                High: 7
        Total issues (by confidence):
                Undefined: 0
                Low: 7
                Medium: 9
                High: 147
Files skipped (0):
```

Plugins (e.g. pickle).

```
The following tests were discovered and loaded:
-----------------------------------------------
        B101    assert_used
        B102    exec_used
        B103    set_bad_file_permissions
        B104    hardcoded_bind_all_interfaces
        B105    hardcoded_password_string
        B106    hardcoded_password_funcarg
        B107    hardcoded_password_default
        B108    hardcoded_tmp_directory
        B110    try_except_pass
        B112    try_except_continue
        B201    flask_debug_true
        B301    pickle
        B302    marshal
        B303    md5
        B304    ciphers
        B305    cipher_modes
        B306    mktemp_q
        B307    eval
```

B308	mark_safe
B309	httpsconnection
B310	urllib_urlopen
B311	random
B312	telnetlib
B313	xml_bad_cElementTree
B314	xml_bad_ElementTree
B315	xml_bad_expatreader
B316	xml_bad_expatbuilder
B317	xml_bad_sax
B318	xml_bad_minidom
B319	xml_bad_pulldom
B320	xml_bad_etree
B321	ftplib
B323	unverified_context
B324	hashlib_insecure_functions
B325	tempnam
B401	import_telnetlib
B402	import_ftplib
B403	import_pickle
B404	import_subprocess
B405	import_xml_etree
B406	import_xml_sax
B407	import_xml_expat
B408	import_xml_minidom
B409	import_xml_pulldom
B410	import_lxml
B411	import_xmlrpclib
B412	import_httpoxy
B413	import_pycrypto
B415	import_pyghmi
B501	request_with_no_cert_validation
B502	ssl_with_bad_version
B503	ssl_with_bad_defaults
B504	ssl_with_no_version
B505	weak_cryptographic_key
B506	yaml_load
B507	ssh_no_host_key_verification

```
        B508    snmp_insecure_version
        B509    snmp_weak_cryptography
        B601    paramiko_calls
        B602    subprocess_popen_with_shell_equals_true
        B603    subprocess_without_shell_equals_true
        B604    any_other_function_with_shell_equals_true
        B605    start_process_with_a_shell
        B606    start_process_with_no_shell
        B607    start_process_with_partial_path
        B608    hardcoded_sql_expressions
        B609    linux_commands_wildcard_injection
        B610    django_extra_used
        B611    django_rawsql_used
        B701    jinja2_autoescape_false
        B702    use_of_mako_templates
        B703    django_mark_safe
```

Filter for high severity issues only:

```
$ bandit -r luigi --severity high -iii

...

--------------------------------------------------
>> Issue: [B605:start_process_with_a_shell] Starting a process with a shell, possib
   Severity: High   Confidence: High
   CWE: CWE-78 (https://cwe.mitre.org/data/definitions/78.html)
   Location: luigi/lock.py:39:13
  More Info: https://bandit.readthedocs.io/en/1.7.4/plugins/b605_start_process_wi
38          cmd = 'wmic path win32_process where ProcessID=%s get Commandline 2> nul
39              with os.popen(cmd, 'r') as p:
40            lines = [line for line in p.readlines() if line.strip("\r\n ") != ""]

--------------------------------------------------
>> Issue: [B103:set_bad_file_permissions] Chmod setting a permissive mask 0o777 on f
   Severity: High   Confidence: High
   CWE: CWE-732 (https://cwe.mitre.org/data/definitions/732.html)
   Location: luigi/lock.py:103:8
  More Info: https://bandit.readthedocs.io/en/1.7.4/plugins/b103_set_bad_file_per
102             os.mkdir(pid_dir)
103             os.chmod(pid_dir, 0o777)
104         except OSError as exc:

--------------------------------------------------

Code scanned:
        Total lines of code: 21186
        Total lines skipped (#nosec): 0

Run metrics:
        Total issues (by severity):
                Undefined: 0
                Low: 122
                Medium: 34
                High: 7
        Total issues (by confidence):
                Undefined: 0
                Low: 7
                Medium: 9
                High: 147
Files skipped (0):
```

Commit hooks

- use commit hooks to run one or more style or auditing tools
- balance between warnings and actionable advice# Type Hints
- Gradually added to Python 3

Defined by various PEPs:

- 483 – The Theory of Type Hints (2014)
- 484 – Type Hints (2014)

And more relevant PEPs:

- 526 – Variable Annotations (2016)
- 544 – Protocols: Structural subtyping (static duck typing) (2017)

- 585 – Type Hinting Generics In Standard Collections (2019)
- 586 – Literal Types (2019)
- 589 – TypedDict: Type Hints for Dictionaries with a Fixed Set of Keys (2019)
- 591 – Adding a final qualifier to typing (2019)
- 593 – Flexible function and variable annotations
- 604 – Allow writing union types as X | Y (2019)
- 612 – Parameter Specification Variables (2019)
- 613 – Explicit Type Alias (2020)
- 647 – User-Defined Type Guards (2020)

Other:

- 3107 – Function Annotations

> Function annotations, both for parameters and return values, are completely optional. Function annotations are nothing more than a way of associating arbitrary Python expressions with various parts of a function at compile-time.

Function annotations are not limited to type hints.

Annotations

- not limited to type hints, but generic way to annotate function parameters and return values (other use cases)

```
def hello(greeting: "greeting word", name: "custom name") -> "result":
    return f"{greeting} from {name}"

print(hello("hello", "world"))
print(hello.__annotations__)

# hello from world
# {'greeting': 'greeting word', 'name': 'custom name', 'return': 'result'}
```

Highlights from PEP-484

> In its basic form, type hinting is used by filling function annotation slots with classes:

A new module is used (e.g. for names None, Any, Union, Tuple, Callable)

> All newly introduced names used to support features described in following sections (such as Any and Union) are available in the typing module.

Example callable:

```
from typing import Callable

def f(g : Callable[..., bool]) -> bool:
    return True
```

```
$ mypy Snippets/TypeHints/call.py
Success: no issues found in 1 source file
```

We can express generics:

```
from typing import Mapping, Set

def notify_by_email(employees: Set[Employee], overrides: Mapping[str, str])
↪   -> None: ...
```

We can define a Type variable:

```
from typing import Sequence, TypeVar

T = TypeVar('T')       # Declare type variable

def first(l: Sequence[T]) -> T:    # Generic function
    return l[0]
```

Type variables can define one or more other types:

> TypeVar supports constraining parametric types to a fixed set of possible types (note: those types cannot be parameterized by type variables). For example, we can define a type variable that ranges over just str and bytes. By default, a type variable ranges over all possible types. Example of constraining a type variable:

```
from typing import TypeVar, Text

AnyStr = TypeVar('AnyStr', Text, bytes)

def concat(x: AnyStr, y: AnyStr) -> AnyStr:
    return x + y
```

Both x and y need to be the *same* type.

> List and List[Any] mean the same

A user defined generic type uses `Generic` type.

```
from typing import TypeVar, Generic
from logging import Logger

T = TypeVar('T')

class LoggedVar(Generic[T]):
    def __init__(self, value: T, name: str, logger: Logger) -> None:
        self.name = name
        self.logger = logger
        self.value = value

    def set(self, new: T) -> None:
        self.log('Set ' + repr(self.value))
        self.value = new

    def get(self) -> T:
        self.log('Get ' + repr(self.value))
        return self.value

    def log(self, message: str) -> None:
        self.logger.info('{}: {}'.format(self.name, message))
```

Generic types

```
from typing import TypeVar, Generic

T = TypeVar('T')

class Node(Generic[T]):
    def  __init__(self, k : T):
        self.k = k

    def __repr__(self):
        return f'{self.k} of type {type(self.k)}'
```

```
node = Node(int)
print(node)

node = Node(123)
print(node)
```

Type Aliases

Support to readability and compact code.

```
from typing import List, Tuple

Book = Tuple[str, str, int]

movies: List[Book] = [
    ("Python", "Andrew", 2005),
    ("Inside Python", "Pete", 2015),
    ("Clean code", "Lee", 2010)
]
```

Covariance and Contravariance

> covariant. This means that the subtyping relation of the simple types are preserved for the complex types.

i.e. is `List[Cat]` a subclass of `List[Amimal]` – if so, then the list type contructor is covariant.

Forward References

> When a type hint contains names that have not been defined yet, that definition may be expressed as a string literal, to be resolved later.

List or list

> In Python 3.9 we won't have to import things like Tuple, List, and Dict from the typing module. Instead, we'll be able to use the standard tuple, list, and dict types for annotation.

Union Types

```
from typing import Union

def handle_employees(e: Union[Employee, Sequence[Employee]]) -> None:
    if isinstance(e, Employee):
        e = [e]
    ...
```

Union type can represent an optional type as well:

```
def handle_employee(e: Union[Employee, None]) -> None: ...
```

Which got an own shorthand:

```
from typing import Optional

def handle_employee(e: Optional[Employee]) -> None: ...
```

Any Type

> A special kind of type is Any. Every type is consistent with Any. It can be considered a type that has all values and all methods. Note that Any and builtin type object are completely different.

It's the type used implicitly:

> A function parameter without an annotation is assumed to be annotated with Any.

NoReturn Type

```
from typing import NoReturn

def stop() -> NoReturn:
    raise RuntimeError('no way')
```

Stub Files

> Stub files are files containing type hints that are only for use by the type checker, not at runtime. There are several use cases for stub files:

- Extension modules

- Third-party modules whose authors have not yet added type hints
- Standard library modules for which type hints have not yet been written
- Modules that must be compatible with Python 2 and 3
- Modules that use annotations for other purposes

Generated with:

-

```python
BORDER_WIDTH = 15

class Window:
    def __init__(self, width, height):
        self.width = width
        self.height = height

def create_empty() -> Window:
    return Window(0, 0)


# $ stubgen example.py
#
# $ cat out/example.pyi
# from _typeshed import Incomplete
#
# BORDER_WIDTH: int
#
# class Window:
#     width: Incomplete
#     height: Incomplete
#     def __init__(self, width, height) -> None: ...
#
# def create_empty() -> Window: ...
```

When to use type checking?

- public APIs, library entry points
- highlight a more complicated piece of logic
- discover bugs and inconsistencies

A few techniques

Beyond basic annotations, there are a few ways to constrain types.

Optional

```
from typing import Optional

string_or_none: Optional[str] = "abc"
```

Optional is a shorthand for Union of None and a type.

- helpful hint
- will lead to mypy warnings when e.g. methods are called on an optional type before None check

Union

```
from typing import Union

def fetch(k:int = 0) -> Union[int, str]:
    if k == 0:
        return 0
    else:
        return "nonzero"
```

- disparate return types
- similar to "Optional", but maybe carrying error messages
- handling different user input
- backwards compatibilty

Literal

- help to reduce number of valid values

Example: Snippets/TypeHints

NewType

- creates a distinct type
- `Derived = NewType('Derived', Base)`

```
from typing import NewType

UserId = NewType('UserId', int)
some_id = UserId(524313)
```

- can help to model stages of an object

> Maybe we have a setup type that goes to different stages, before it is done. We could distinguish the same object during this cycle.

```
SetupDone = NewType('SetupDone', Setup)
```

Final

- restrict a type from changing its value

Collections

- use generic collection annotations
- https://docs.python.org/3/library/typing.html#generic-concrete-collections
- Dict, List, Set, FrozenSet, …

Dictionaries

- use TypedDict to annotate a dictionary

```
class Point2D(TypedDict):
    x: int
    y: int
    label: str

a: Point2D = {'x': 1, 'y': 2, 'label': 'good'}  # OK
b: Point2D = {'z': 3, 'label': 'bad'}           # Fails type check

assert Point2D(x=1, y=2, label='first') == dict(x=1, y=2, label='first')
```

- model more complex structures, e.g. api responses

Other considerations

- try to make invalid states unrepresentable

Example: Split a type carrying both a value and error conditions into two parts.

Other tools

- pyre
- pysa

> Pyre ships with Pysa, a security focused static analysis tool we've built to reason about data flows in Python applications at scale.

Allows to mark tainted code, e.g. a source (user input) and sinks (shell calls) to check for possible remove code executions.

Input needs to be sanitized, and can be marked manually. # Data Validation with Pydantic

- allows to model data, with type annotations

```
from pydantic import BaseModel

class User(BaseModel):
    id: int
    name = 'Jane Doe'
```

Models support a variety of extra methods, e.g. for exporting like `json`, `dict` or JSON schema. Validation can be circumvented with `construct`.

Examples: Snippets/Pydantic# Configuration with Dynaconf

- https://www.dynaconf.com/

Supports various file formats:

- .toml - Default and recommended file format.
- .yaml|.yml - Recommended for Django applications. (see yaml caveats)
- .json - Useful to reuse existing or exported settings.
- .ini - Useful to reuse legacy settings.
- .py - Not Recommended but supported for backwards compatibility.
- .env - Useful to automate the loading of environment variables.

To initialize:

```
$ dynaconf init -f toml
```

Will set up a few files:

```
.
├── config.py       # Where you import your settings object (required)
├── .secrets.toml   # Sensitive data like passwords and tokens (optional)
└── settings.toml   # Application setttings (optional)
```

The config file reaches out to the file:

```
from dynaconf import Dynaconf

settings = Dynaconf(
    settings_files=['settings.toml', '.secrets.toml'],
)
```

Configuration module can be imported and used:

“‘python from config import settings

assert settings.key == “value” assert settings.number == 789 assert settings.a_dict.nested.other_level == “nested value” assert settings[‘a_boolean’] is False assert settings.get(“DONTEXIST”, default=1) == 1 “‘# Defensive Coding

Testing

- testing edge cases

Design by Contract

- not supported by the language
- ensure correctness of inputs
- validation

Settings Limits

- timeouts
- retries
- memory contraints
- overflows
- denial of service

Reviews

- code review
- web application security risks: https://owasp.org/www-project-top-ten/
- proxies

Security

- validate user input
- fail fast