Decoupled code

Good research code

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Lesson 2

Keep things decoupled

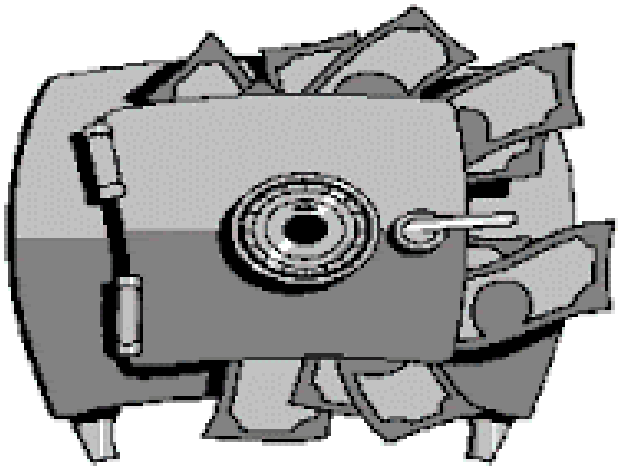
Spaghetti code

Development AntiPattern:

Spaghetti Code

spa·ghet·ti code [Slang] an undocumented piece of software source code that cannot be extended or modified without extreme difficulty due to its convoluted structure.

Un-structured code
is a liability



Well structured code
is an investment.

Do you know when your code smells?

- Maybe your code is written in a way where you're doing a little bit of everything all at once
- e.g. `wave_clus`
  - very useful software to sort spikes
  - has a GUI in Matlab GUIDE
  - GUIDE makes it exceptionally hard to write good code
  - Picked it because it's real code
- This stuff can happen in Matlab or in Python!

Sample code

Link.

What's going here?

This is a callback for a function in a GUI for spike sorting.

- Does many things at once
  - Manipulates the GUI
  - Modifies data
  - Reads a jpg file?
- Uses magic numbers and magic columns
- Uses various string formatting functions and `eval`
- Big function
- Not complex, but it's complicated

Tightly coupled

- When code does a lot of unrelated things at once, it becomes very hard to reason about.
- Let's say your results are weird, are they weird because. . .
  - the data is bad?
  - you're loading the data wrong?
  - your model is incorrectly implemented?
  - your model is inappropriate for the data?
  - you statistical tests are inappropriate for the data distribution?

Uncouple and simplify

- Keep each of the boxes separate with minimal interface
  - Separation of concerns:
    - Example: your data loading function should just load data
    - Your computation functions shouldn't load data, they should just compute
- Make each of the boxes small
  - Don't make giant monolithic functions
  - Make functions which are small
    - A screen's worth, 80 columns, 50 lines
- Avoid side effects, prefer pure functions

What's a side effect?

In computer science, an operation, function or expression is said to have a side effect if it modifies some state variable value(s) outside its local environment, that is to say has an observable effect besides returning a value (the main effect) to the invoker of the operation. State data updated "outside" of the operation may be maintained "inside" a stateful object or a wider stateful system within which the operation is performed. Example side effects include modifying a non-local variable, modifying a static local variable, modifying a mutable argument passed by reference, performing I/O or calling other side-effect functions. (Wikipedia)

Side effects

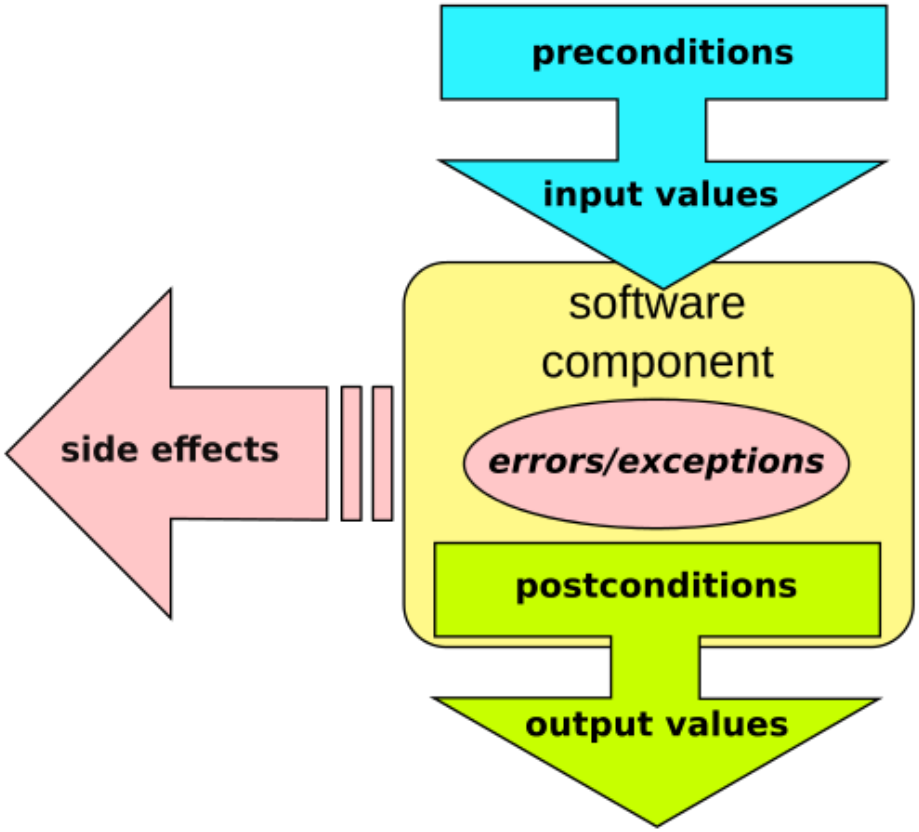


Figure 2: From Wikipedia

A function with side effects

Q: what will be printed?

```
def reversi(arr):
    """Reverses a list."""
    for i in range(len(arr) // 2):
        arr[-i - 1], arr[i] = arr[i], arr[-i - 1]
    return arr
```

```
>>> a = [0, 1, 2]
>>> b = reversi(a)
>>> print(b)
>>> print(a)
```

A function which changes its arguments

```
In [12]: def reversi(arr):
    ...:     """Reverses a list."""
    ...:     for i in range(len(arr) // 2):
    ...:         arr[-i - 1], arr[i] = arr[i], arr[-i - 1]
    ...:     return arr
    ...:

In [13]: a = [0, 1, 2]

In [14]: b = reversi(a)

In [15]: print(b)
[2, 1, 0]

In [16]: print(a)
[2, 1, 0]
```

Figure 3: This function mutates its arguments

Side effects

- Modifying arguments
- Printing
- Making API calls
- Changing globals

Side effects are not the best

- Stuff happens outside of the normal flow from arguments $\rightarrow$ return value
- Need to know state of function to understand it
- Hard to test
- Let's box them
  - You can use closures or classes to encapsulate state

Demo

- `fib.py`
- Fibonacci sequence, $F(n) = F(n-1) + F(n-2)$
- Memoization

Learn more about your language

- Sometimes (but not always!), code smells come from lack of knowledge
  - E.g. using magic column numbers in a raw numpy array rather than named columns in pandas because you don't know pandas
  - Using unnamed dimensions in numpy rather than xarray
  - Using + and bespoke casting for string formatting rather than the one true solution, the f-string
- Take time to learn more about the language you use
- Coming from Matlab? I have three tutorials: [1], [2], [3]

Enough theory!

Let's de-couple CKA!

Background on centered kernel alignment

Q: how can we compare how different brain areas and artificial neural networks represent the world?

A: Choose a standard battery of stimuli, measure responses across systems, compare the responses between the systems. Many approaches, including:

- forward encoding models (e.g. ridge regression)
- canonical correlation analysis (CCA)
- representational similarity analysis (RSA).

CKA

Kornblith et al. (2019) propose a new method to compare representations. You can think of it as a generalization of the (square of the) Pearson correlation coefficient, but with matrices instead of vectors.

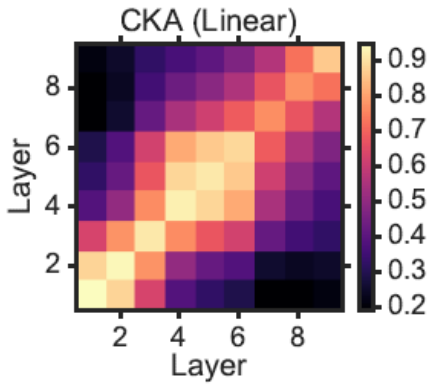


Figure 4: Alignment between layers of two neural nets initialized with different seeds

Importantly, CKA is not implemented in scipy or sklearn, github gives very few hits [1]... it's real research code!

Centered kernel alignment

- We collect the responses of each system to our battery of n stimuli into matrices $\mathbf{X}, \mathbf{Y}$.
- $\mathbf{X}, \mathbf{Y}$ have shape nxk, nxl, and k and l are not necessarily the same.
- Center $\mathbf{X}, \mathbf{Y}$ so each column has 0 mean, then:

$$CKA(\mathbf{X}, \mathbf{Y}) = \frac{||\mathbf{X}^T\mathbf{Y}||_2^2}{||\mathbf{X}^T\mathbf{X}||_2||\mathbf{Y}^T\mathbf{Y}||_2}$$

- Min 0, max 1
- Check: if $\mathbf{X}$ and $\mathbf{Y}$ are one-dimensional, then $CKA = \rho(\mathbf{X}, \mathbf{Y})^2$.

Open discussion

Q: What's not ideal about this code?

`research_code.cka_not_great.py`

Pain points

- IO, computation and plotting are all in one big blob
- Solution: isolate the computation in its own function independent of IO
- Put the controller in the `main` function, hide behind `__name__ == "__main__"`
  - Avoids module variables in Python
  - Makes the code importable

Live coding!

(the result is `cka_step2.py`)

You can apply this advice at a project-wide level as well

Advice from van Vliet (2020):

1. **Each analysis step is one script**
2. **A script either processes a single experimental replicate, or aggregates across replicates, never both.**
3. One master script to run the entire analysis
4. **Save all intermediate results**
5. Visualize all intermediate results
6. **Each parameter and filename is defined only once**
7. Distinguish files that are a part of the official pipeline

Decoupling configuration

- Keep your configuration our of your code
  - Use `argparse` to specify options via the command line
  - Keep configuration options located in an importable `config.py` file
  - Use `python-dotenv` to store secrets in a `.env` file

Lesson 2

- Keep things decoupled
- By keeping things decoupled, you can think about one part of your program at a time
- Save your WM slots
- Your 5-minute exercise: take existing code and wrap it in `main`