Evil Code for Wicked Problems, part 4

A Research Programmer's Guide to World Domination– in Python.
a.k.a. *Lecture Notes, Automated SE*, CS, NC State, Fall'15

by Tim Menzies
#attentionDeficitSquirrel
Download: see `book.pdf` at https://github.com/txt/evil
This version: June 20, 2015

About this book

This book is a "how to" guide about model-based reasoning using data mining and search-based tools (with examples taken from software engineering). It is intended for graduate students taking a one semester subject in advanced programming methods as well as researchers developing the next generation of model-based reasoning tools.

Using Python 2.7, the book builds (from the ground up) numerous tiny tools that can tame seemingly complex tasks. The combined toolkit, called RINSE, offers four kinds of functionality:

1. It *represents* models using domain-specific languages;
2. It supports *inference* across the multiple goals of those models using multi-objective optimization.
3. It shows how to succinctly *summarize* that inference using data miners;
4. It has many tools for the *evaluation* of different inference methods.

RINSE is a not some shiny end-user click-and-point GUI package. Rather, it is a starter-kit that demonstrates an novel model-based approach to problem solving where programmers mix and match and extend data miners and multi-objective optimizers.

RINSE was written using the mantra "less is more". Whenever it was found that small parts of the the code handled most of the functionality, then the extra functionality was ejected. This resulted in a (very) small code base which can be readily browsed, learned, taught, and changed.

Content Advisory

This book contains strong language, weakly typed (and tapped with glee).

This book may contain excessive or gratutious fun– as well as ideas that some readers may (or may not) find disturbing. This book does not necessarily believed or endorse those ideas- but plays with them anyway (and asks you to do the same).

This book may include heresies, not suitable for anyone who believes in established wisdom, without adequate experimentation. It is intended for mature audiences only; i.e. those old enough to know there is much left to know.

This book may (or may not) contain peanuts or tree nut products.

Batteries not included.

Contents

Source Code Availability and Copyleft

To download the RINSE code, see http://github.com/txt/mase. The software associated with this book is free and unencumbered and released into the public domain.

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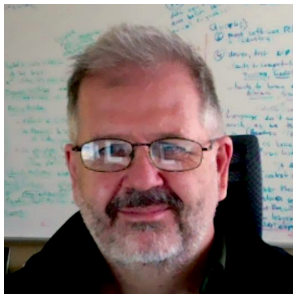
About the Author



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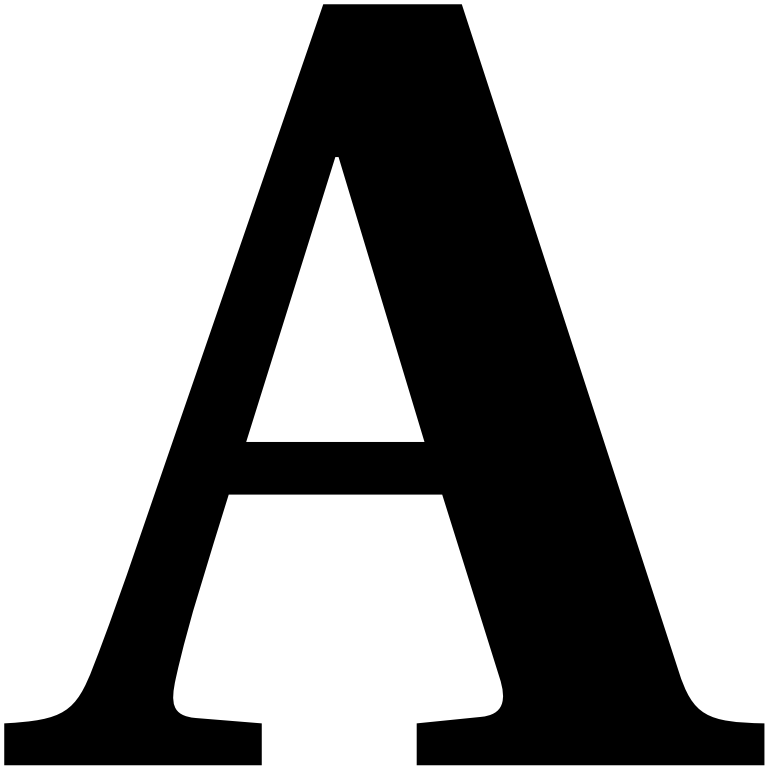
In his career, he has been a lead researcher on projects for NSF, NIJ, DoD, NASA, USDA, as well as joint research work with private companies. He is the author of over 230 referred publications; and is one of the 100 most cited authors in software engineering out of over 80,000 researchers.

Prof. Menzies is an associate editor of IEEE Transactions on Software Engineering, Empirical Software Engineering and the Automated Software Engineering Journal. His community service includes co-founder of the PROMISE project (storing data for repeatable SE experiments); co-program chair for the 2012 conference on Automated SE and the 2015 New Ideas and Emerging Research track at the International Conference on SE; and co-general chair for 2016 International Conference on Software Maintenance and Evolution.

Prof. Menzies can be contacted at `tim.menzies@gmail.com`.



(An Introduction)

1 Welcome to the Evil Plan

"The world is a dangerous place to live, not because of the people who are evil, but because of the people who don't do anything about it." - Albert Einstein

The evil plan (by programmers) to take over the world is progressing nicely. Certain parts of that plan were initially somewhat undefined. However, given recent results, this book can now fill in the missing details from part4 of that plan.

But first, a little history. As all programmers know, this plan is now decades old. Part one was for programmers to adopt a meek and mild persona (possibly even boring and dull).

Part two was, under the guise of that persona, ingratiated ourselves to government and indistrial agenices (education, mining, manufacturing, etc etc). Once there, make our work essential to their day to day opertion. Software is now a prime driven in innovation and all aspects of economic development. Software mediates most aspects of our daily lives such as the stock market models that control the economy; the probablistic models that recommend what books to read; and the pacemakers that govern the beating of our heart.

After that, part three was to make more material available for our inspection and manipluation. To this end, the planet was enclosed a digital network that grants us unprecendented access to petabytes of sensors and effectors. Also, by carefully seeding a few promienet examples of successful programmers (Gates, Jobs, Zuckerburg, thanks guys!), we convinced a lot of people to write lots of little tools, each of which represent or control some thing, somewhere.

Part four was a little tricky but, as shown in this book, it turned out not to be too hard. Having access to many models and much data can be overwhelming– unless some GREAT SECRET can be used to significantly simply all that information. For the longest time, that GREAT SECRET was unknown. However, recent advances have revealed that if we describe something in N dimensions, then there is usually a much smaller set of M dimensions that contain most of the signal. So GREAT SECRET is that is it very easy (and very fast) to find then exploit those few number of M dimensions for solving seemingly complex problems.

With those controllers in hand, we are now free to move to part five; i.e. taking over the world. The truly evil part of this work is this: *now you know you have the power to change the world.* This also means that (evil laugh) *now you have the guilt if you do not use that power to right the wrongs of the world.* So welcome to a lifetime of discontent (punctuated by the occasionaly, perhaps fleerting, truimphs) as you struggle to solve a very large number of pressing problems facing humanity.

'Nough said. Good luck with that whole world domination thing. One tip: if at first you cannot dominate the whole thing, start out with something smaller. Find some people who have problems, then work with them to make changes that help them. Remember: if you don't try then you won't be able to sleep at night. Ever again (evil laugh).

1.1 Research Programming

Silliness aside, this book is about how to be a *research programmer*. Research programmer's understand the world by:

- Codify out current understanding of "it" into a model.
- Reasoning about the model.

We take this term "research programmer" from Ph.D. Steve Guao's 2012 dissertation.

1.1.1 Challenges with Research Programming

Research programming sounds simple, right? Well, there's a catch (actually, there are several catches).

Firstly, models have to be written and it can be quite a task to create and validate a model of some complex phenomenon.

see also list in sbse14

Secondly, many models related to *wicked problems*; i.e.~problems for which there is no clear best solution. Tittel XXXWorse still, some models relate to _wicked there is final matter of the *goals* that humans want to achieve with those models. When those goals are contradictory (which happens, all too often), then our model-based tools must negotiate complex trade offs between different possibilities.

Thirdly, if wicked problems were not eough, there is also the issue of uncertainty. Many real world models contain large areas of uncertainty, especially if that model relates to something that humans have only been studying for a few decades.

Fourthly, even if you are still not worried about the effectiveness of reserach problem, consider the complexity of real-world phenomonem. Many of these models are so complex that we cannot predict what happens when the parts of that model interact.

Sounds simple, right? Well, there's a catch. Many models related to *wicked problems*; i.e. problems for which there is no clear best solution. Tittel XXXWorse still, some models relate to _wicked there is final matter of the *goals* that humans want to achieve with those models. When those goals are contradictory (which happens, all too often), then our model-based tools must negotiate complex trade offs between different possibilities.

If wicked problems were not eough, there is also the issue of uncertainty. Many real world models contain large areas of uncertainty, especially if that model relates to something that humans have only been studying for a few decades.

And if you are still not worried about the effectiveness of reserach problem, consider the complexity of real-world phenomonem. Many of these models are so complex that we cannot predict what happens when the parts of that model interact.

1.1.2 Parts

- Domain specifc langauges (representation)
- execution (nuktu-objective ootiization)
- evaluation (statistical methods for experimental sciencetists in SE)
- Philophsopy (about what it means to know, and to doubt)

1.1.3 Implications for Software Engineering

Note that research programming changes the nature and focus and role of 21st century software engineering:

- Traditionally, software engineering is about services that meet requirements.
- But with research programming, software engineering is less about service than about search. Research programming's goal is the discovery of interesting features in existing models (or perhaps even the evolution of entirely new kinds of models).

For example, old-fashioned software engineerings might explore small things like strings or "hello world". But with research programmers explore **BIG** things like String Theory or "hello world model of climate change and economic impacts".

The GREAT SECRET

Example

brook's law. DSL in python of CM. data mining.

B

(Before we begin)

2 Before we Begin

Our goals are lofty- introducing a new paradigm that combines data mining with multi-objective optimization. And doing so in such a way that even novices can understand, use, and adapt these tools for a large range of new tasks.

But before we can start all that, we have to handle some preliminaries. All artists, and programmers, should start out as apprentices. If we were painters and this was Renaissance Italy, us apprentices would spend decades study the ways of the masters, all the while preparing the wooden panels for painting; agrinding and mixing pigments; drawing preliminary sketches, copying paintings, and casting sculptures. It was a good system that gave us the Michelangelo and Da Vinci who, in turn, gave us the roof of the Sistine Chapel and the Mona Lisa.

In terms of this book, us apprentices first have to become effective Python programmers. The rest of this chapter offers:

- Some notes on useful web-based programming tools
- Some pointers on learning Python
- Some start-up exercises to test if you have an effective Python programming environment.

2.1 Useful On-Line Tools

This book was written using the following on-line tools. There exists many other great, readily available, tools (and if you know of better ones, then please let me know (then maybe I'll switched over).

2.1.1 Stackoverflow

To find answers to nearly any question you'll ever want to ask about Python, go browse:

```
http://stackoverflow.com/questions/tagged/python
```

2.1.2 Cloud9

If you do not want to install code locally on your machine, then there are many readily-available on-line integrated development environments.

For example, to have root access to a fully-configured Unix installation, you could go to

```
http://c9.io
```

One tip is to host your Cloud9 workspace files on Github. As of June 2015, the procedure for doing that was:

- Go to Github and create an empty repository.
- Log in to Cloud9 using your GitHub username (at `http://c9.io`, there is a button for that, top right).
- Hit the green *CREATE NEW WORKSPACE* button
  - Select *Clone from URL*;
  - Find *Source URL* and enter in `http://github.com/you/yourRepo`
  - Wait ten seconds for the screen to change.
  - Hit the green *START EDITING* button.

This will drop you into the wonderful Cloud9 integrated development environment. Here, you can edit code and (using the above `Makefile`) run `make typo` to backed up your code outside Cloud9, over at `Github.com` (which means that if ever Cloud9 goes away, you will still have your code).

The good news about Cloud9 is that it is very easy to setup and configure. The bad news is that each Cloud9 workspace has the same limits as Github- a 1GB size limit. Also, for CPU-intensive applications, shared on-line resources like Cloud9 can be a little slow. That said, for the newbie, Cloud9 is a very useful tool to jump start the learning process.

For sites other than Cloud9, see Koding, Nitrous.IO and many more besides.

2.1.3 Github

All programmers should use off-site backup for their work. All programmers working in teams should store their code in repositories that let them fork a branch, work separately, then check back their changes into the main trunk.

There are many freely-available repository tools. Github is one such service that supports the `git` repository tool. Others include SourceForge, BitBucket, and many more besides. Github has some special advantages:

- It is the center of vast social network of programmers;
- Github support serving static web sites straight from your Github repo.
- Many other services offer close integration with Github (e.g. the Cloud9 tool discussed below).

For more information, go to:

```
http://github.com
```

The good news about Github is that it is very easy to setup and configure. The bad news is that each Github repository has a 1GB size limit. But that is certainly enough to get us started.

Regardless of whether or not you are using Github, you can use it to access the source code used in this paper:

```
# If you used "git":
git clone https://github.com/txt/evil
# If you just want the files:
wget https://github.com/txt/evil/archive/master.zip
```

For Linux/Unix/Mac users, I add the following tip. In each of your repository directories, add a `Makefile` with the following contents.

```
# File:  setup/Makefile (from github.com/txt/evil)
# Usage: make
typo:   ready
    @- git status
    @- git commit -am "saving"
    @- git push origin master # insert your branch names here

commit: ready
    @- git status
    @- git commit -a
    @- git push origin master

update: ready
    @- git pull origin master

status: ready
    @- git status

ready:
    @git config --global credential.helper cache
    @git config credential.helper 'cache --timeout=3600'

timm:  # <== change to your name
    @git config --global user.name "Tim Menzies" #<== your name
    @git config --global user.email tim.menzies@gmail.com #<== your email

tests: *ok.py
    @$(foreach f,$^,\
            printf "\n========= $f =========\n\n";\
            python $f;)
```

This `Makefile` implements some handy shortcuts:

- `make typo` is a quick safety save– do this many times per day;
- `make commit` is for making commented commits– use this to comment any improvements and/or degradation of functionality.
- `make update` is for grabbing the latest version off the server– do this at least at the start of each day.
- `make status` is for finding files that are not currently known to Github.
- `make ready` remembers your Github password for one hour– use this if you use `make typo` a lot and you want to save some keystrokes.
- `make timm` should be used if Github complains that it does not know who you are. Before running this one, edit this rule to include your name and email.
- `make tests` is a little unit test engine, discussed later.

Tip:

- IMPORTANT: When writing a `Makefile`, all indentations have to be made using the tab character, not 8 spaces.

Of course, there are 1000 other things you can do with a `Makefile`. For example, this book is auto-generated by a `Makefile` that automatically extracts comments and code from my Python source code, then compiles the comments as Markdown, then used the wonderful `pandoc` tool to compile the Markdown into Latex, then converts the Latex to a `.pdf` file. Which is all interesting stuff– but beyond the scope of this book.

2.2 Learning Python

2.2.1 Why Python?

I use Python for two reasons: readability and support. Like any computer scientist, I yearn to use more powerful languages like LISP or Javascript or Haskell (Have you tried them? They are *great* languages!). That said, it has to be said that good looking Python *reads* pretty good– no ugly brackets, indentation standards enforced by the compiler, simple keywords, etc.

Ah, you might reply, but what about other beautiful languages like CoffeeScipt or Scala or insert yourFavoriteLanguageHere? It turns out that, at the time of this writing, that there is more tutorial support for Python that any other language I know. Apart from the many excellent Python textbooks, the on-line community for Python is very active and very helpful; e.g. see stackoverlow.com.

2.2.2 Which Python?

This book uses Python 2.7, rather than the latest-and-greatest version, which is called Python3. Why?

The problems with Python3 are well-documented and being actively addressed by the Python community. In short, many large and useful Python libraries are not yet unavailable in Python3 so many developers are sticking with the older version.

This situation may change in the near future so, in the coding standards discussed below, we discuss how to use Python3 idioms while coding in Python2. This will make our eventual jump to Python3 much easier.

2.2.3 Installing

To get going on Python, you will need a *good* Python environment. You may already have a favorite platform or interactive development environment, in which case you can use that (and if not, you might consider using the Cloud9 environment discussed above). To check if your Python environment is *good*, try changing and installing some things.

Note that I use Mac/Linux/Unix so all the examples in this book will be from a Unix-ish command-line prompt. For Windows users, you can

- Use Google to find equivalent instructions for your platform;
- Use some on-line IDE like Cloud9 (simple!).
- Install a Linux in a virtual environment on top of Windows; e.g. using VirtualBox and Ubuntu (warning: not so simple).

Code Indentation Firstly, change the code indent to 2 spaces. Many editors have this option. For example, for the editor I use (EMACS), those magic setting can be found the `add-hock 'python-model-hook` of `.emacs` (available on-line at `https://github.com/timm/timmnix` in the `dotemacs` file).

Get the Package Managers Secondly, make sure you have installed the `pip` and `easy_install` tools (these are tricks for quickly compiling Python code). Try running

```
pip -h
easy_install -h
```

Tips:

- If these are not installed them Google for installation instructions. See also `https://pypi.python.org/pypi/setuptools` (which has hints for Windows users as well as those using Linix/Unix/Mac).
- If you ever run this code and you get permission errors or some notice that you cannot update some directories, then run as superuser (by the way, one nice thing about Cloud9 is that you have superuser permission on your workspaces). To run code as superuser, in Linux/Unix/Mac, preface with `sudo`; e.g. `sudo pip` or `sudo pip_install`

Use the Package Managers Thirdly, do some installs of various packages. Note that we will make extensive use of all of the following.

Package1: watcher. Enable a *watcher* on files that are being edited. Every time you save the *watched* file, it is re-executed (so you get rapid feedback on your progress):

```
sudo pip install rerun
```

Example: establish a *watch* on `lib.py`:

```
rerun "python lib.py"
```

Now, if ever we change any files in this directory, then this code will rerun `python lib.py`– which is a nice trick for getting very fast feedback on code.

Package2: 2D plotting with `matplotlib`.

Run this code.

```
sudo pip install matplotlib
```

Example: The following code, shows how to generate a plot within Cloud9 using `matplotlib`. To check if you have have a *good* Python environment, check you can run this code using `python demoMatplot.py`. If you do not know Python yet, do not try to understand the code (just download it and run it).

```
# File : setup/demoMatplot.py (from github.com/evil)
# Usage: python demoMatplot.py
#                                          TRICKS
import matplotlib
matplotlib.use('Agg')     #.................. 1
import matplotlib.pyplot as plt

def lines(xlabel, ylabel, title,
          f="lines.png",   #.................. 2
          xsize=5,ysize=5,lines=[]):
  width = len(lines[0][1:])
  xs = [x for x in xrange(1,width+1)]
  plt.figure(figsize=(xsize,ysize))  #......... 3
  plt.xlabel(xlabel)
  plt.ylabel(ylabel)
  for line in lines:
    plt.plot(xs,  line[1:],  #.................. 4a
             label = line[0])   #.......... 4b

  plt.locator_params(nbins=len(xs)) #.......... 5
  plt.title(title)
  plt.legend()
  plt.tight_layout()                #.......... 6
  plt.savefig(f)

lines("days","production",  #.................. 7
      "Fruit output",
      xsize=3,ysize=3,lines=[
      ["apples",4,3,2,1],
      ["oranges",9,4,1,0.5]])
```

If the code works you should see the following file `lines.out`:

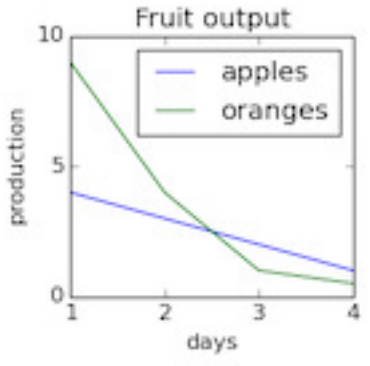


Figure 1: Example, 2d plotting from Python, using `matplotlib`

If you do know Python, they I add notes on seven little tricks in the above code:

1. Add this line *right after* importing `matplotlib`. If absent, then when used in a non-X-server environment (e.g. Cloud9), the code crashes.
2. Note the use of default parameters. By default, this function writes to `lines.png` but this can be changed when the function is called.
3. Here we can change the default size of a plot (which defaults to five inches square– do you know why? hint: look at the default parameters of the function).

4. The line label and the line data is pulled from the data passed to the function. To see that, have a look at the last like of the code where `orange` is the first item in the list and the rest is data.
5. This is a hack to stop `matplotlib` adding in ticks like "1.5". With this hack, the number of ticks is equal to the number of items in each line to be plotted.
6. Another hack. Once we resize a plot, sometimes the label text gets cut off. The fix is to use a `tight\_layout`.
7. A sample call to this function.

Package3: some data miners. If you've got `matplotlib` working, then the next test is to install a more complex package like `scikit-learn`. This is a nice collection of very useful data mining tools. The following code will install `scikit-learn` on Cloud9 (and for install instructions for other platforms, Google *sklearn*). If you do not know bash scripting, don't try to understand the code, just run it using `bash sk.sh`.

```
# File    : setup/sk.sh (from github.com/txt/evil)
# Usage   : bash sk.sh
installingBuildDependencies() {
  sudo apt-get install \
    build-essential python-dev python-setuptools \
    python-numpy python-scipy \
    libatlas-dev libatlas3gf-base
}
BLASandLAPACK() {
 sudo update-alternatives --set libblas.so.3 \
    /usr/lib/atlas-base/atlas/libblas.so.3
 sudo update-alternatives --set liblapack.so.3 \
    /usr/lib/atlas-base/atlas/liblapack.so.3
}
matplotlib() { # just incase you have not done matplotlib yet
  sudo apt-get install python-matplotlib
}
sklearn() {
  pip install --user  --install-option="--prefix=" -U scikit-learn
}
installingBuildDependencies
BLASandLAPACK
matplotlib
sklearn
```

To check if this all works, then run the following code and look for a generated image file called `sk.png`. Once again, if you do not know Python yet, don't try to understand this code; just run it using `python sk.py`

```
# File:  setup/sk.py (from github.com/txt/evil)
# Usage: python sk.py
from sklearn import datasets
from sklearn.cross_validation import cross_val_predict
from sklearn import linear_model
import matplotlib
matplotlib.use('Agg')
import matplotlib.pyplot as plt

lr = linear_model.LinearRegression()
boston = datasets.load_boston()
y = boston.target
predicted = cross_val_predict(lr, boston.data, y, cv=10)
fig,ax = plt.subplots()
ax.scatter(y, predicted)
ax.plot([y.min(), y.max()], [y.min(), y.max()], 'k--', lw=4)
ax.set_xlabel('Measured')
ax.set_ylabel('Predicted')
fig.savefig('sk.png')
```

If that works, then the file `sk.png` should look like this:

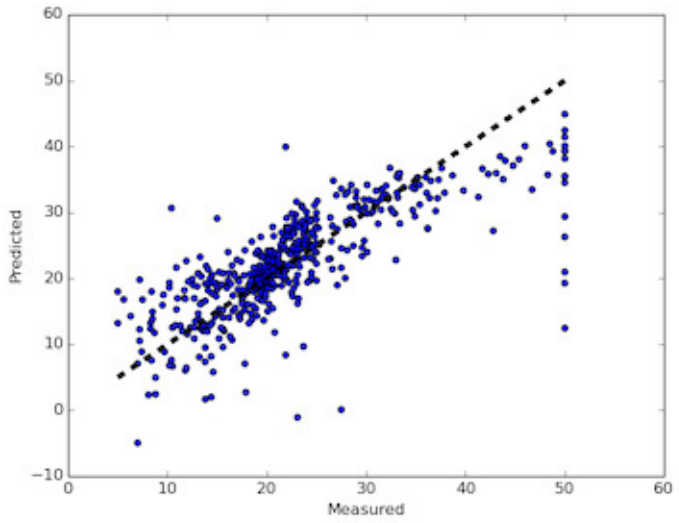


Figure 2: Predictions generated by a machine learner.

2.2.4 Python 101

There are many great tools for learning Python, including all the on-line tools listed above.

In terms of a textbook, I highly recommend *How to Think Like a Computer Scientist* by Allen Downey, which can be purchased as a paper book or viewed or downloaded from `www.greenteapress.com/thinkpython`. All the source code from that book is available on-line at:

```
https://github.com/AllenDowney/ThinkPython
```

If you liked that book, it would be good manners to make a small donation to Prof. Downey at that website– but that is entirely up to you.

Note that there are Python3 versions of this code, available on the web. Try to avoid those.

In terms of a three week teach yourself program, I recommend the following.

- **Week1** Read chapters one to four. *Do* exercises 3.1,3.2,3.3,3.4,3.5. *Do* install `Swampy` *Do* exercise 4.2,4.3 (but makeIn terms of a three-week teach-= yoAt the time of this writing, at

tutorial mater

2.2.5 Installing a "Good" Python Environment

2.2.6 Python Standards

This textbook uses Python 2.7 for its code base. Of course, it is tempting to use Python3 but there are still too many Python packages out there t

2.3 Mantras

2.3.1 "Do go coding, go for feedback"

2.3.2 "Red, Green, Refactor"

2.3.3 "Write Less Code"

Holzmann. true

2.3.4 "Stop writing classes"

Jack Diederich

2.3.5 "That needs a DSL"

Domain specific languages

2.4 Homework

2.4.1 Homework1

- Do: get an account at `http://github.com`. Hand-in: your Github id.
- Show that you have a *good* Python environment by installing
- Generate some pretty print python (2 space indent)

3 Pandoc with citeproc-hs

?

References

John Doe and Jenny Roe. Why water is wet. In Sam Smith, editor, *Third Book*. Oxford University Press, Oxford, 2007.