Open Source Software for Structural Monitoring & Assessment

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Monash University

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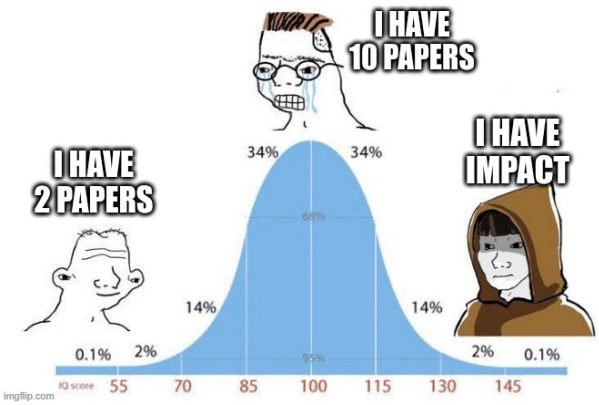
I HAVE
10 PAPERS
I HAVE
2 PAPERS
I HAVE
IMPACT
34%
34%
14%
14%
0.1%
2%
2%
0.1%
68%
95%
IQ score
55
70
85
100
115
130
145
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Goals

To highlight the route to maximum productivity (research & commercial):

- limitations in conventional thinking
- leveraging existing tools
- opening-up to being open

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Closed-source
proprietary software
Open-source
collaborative
software
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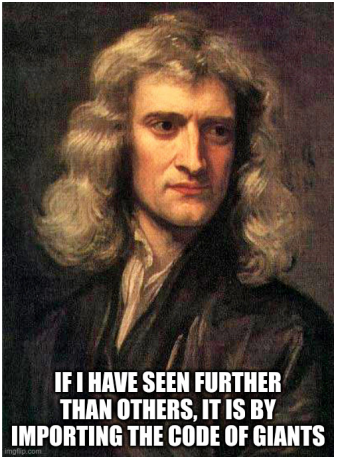
Why Open-Source?

- Science is collaborative
- Repeatability
- Maximize impact
- Accelerate progress



Open Science

An article about a computational result is advertising, not scholarship. The actual scholarship is the full software environment, code and data, that produced the result.

Buckheit and Donoho (1995)

Reproducible Science

advertising:
text & final
results only

science:
text, code &
data available,
linked & licensed

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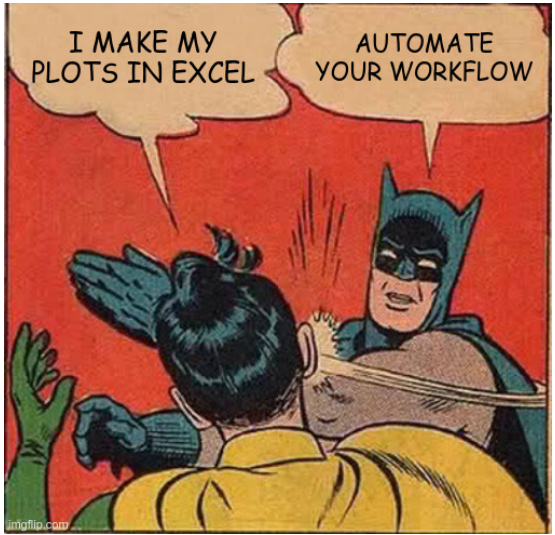
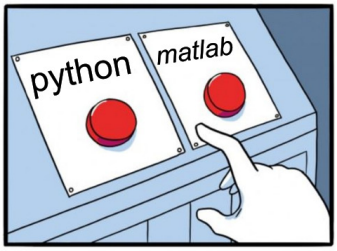

I MAKE MY PLOTS IN EXCEL
AUTOMATE YOUR WORKFLOW
imgflip.com

Why Python?

Python is not the best language for anything... but it is the second best language for everything

Michael Kennedy *Talk Python To Me*



Simplicity

In most cases, **speed of development** is often primary; not always **execution speed**.

Python is really easy to learn:

- very clean & uncluttered syntax
- enormous range of resources availabe

Interoperability

Python is a glue:

- High-level access to low-level libraries in FORTRAN, C, C++, etc
- Chain workflows from DAQ, to data analysis, to webpage dashboards

Ecosystem

Python has libraries for everything

- *Batteries are included* - the python standard library
- Largest third-party library ecosystem

Powerful

Python is a full-spectrum language:

- **scripting**: A few lines of code, e.g. daily web query
- **modules**: A collection of functions, e.g. `genmcq`
- **packages**: A collection of modules, e.g. `ospgrillage`
- **apps**: GUI or web app, e.g. `DropBox`
- **enterprise**: Large scale app, e.g. `Instagram`, `FaceBook`

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My research is going well
I'll just use Excel for this bit
Why is everything hard?
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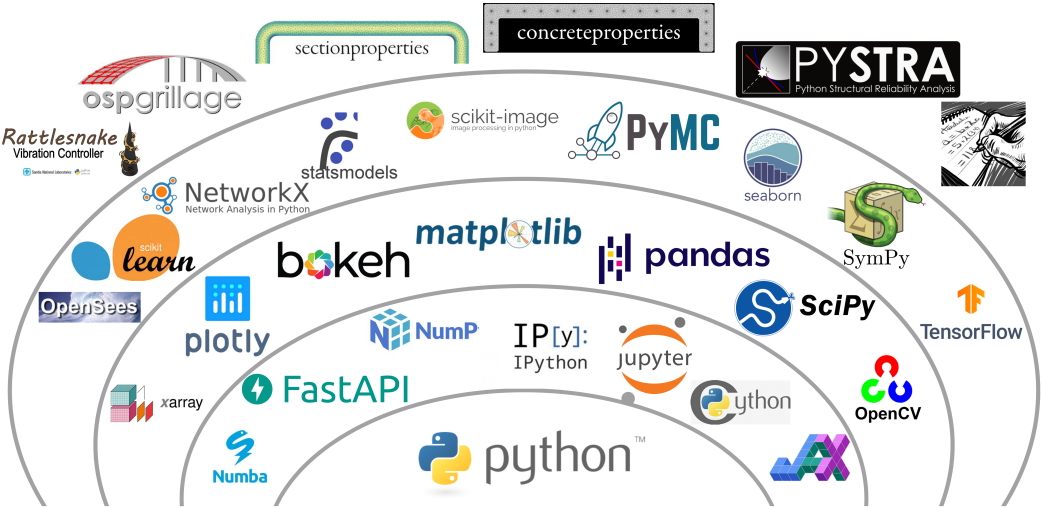
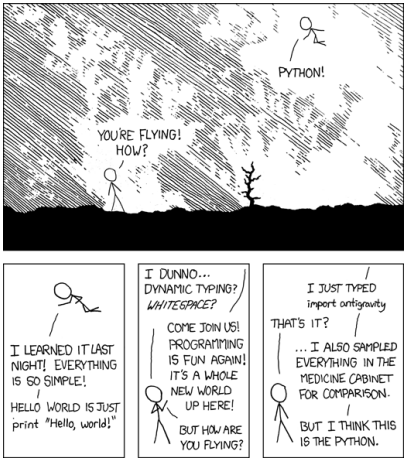
Overview


sectionproperties
concreteproperties
ospgrillage
PYSTRA
Python Structural Reliability Analysis
Rattlesnake
Vibration Controller
statsmodels
scikit-image
image processing in python
PyMC
seaborn
NetworkX
Network Analysis in Python
scikit
learn
bokeh
matplotlib
pandas
SymPy
OpenSees
plotly
NumPy
SciPy
TensorFlow
IP[y]:
IPython
jupyter
xarray
FastAPI
Cython
OpenCV
Numba
python™

Basic Tools

- `import antigravity`: Python has an enormous standard library:
- **NumPy**: Numerical library, linear algebra, etc.
- **SciPy**: Scientific python, e.g. ODEs, sig proc, etc.
- **Pandas**: Tabular data exploration & manipulation
- **Matplotlib**: Plotting library with total control
- **SymPy**: Symbolic computation
- **Jupyter-Lab**: Notebook interface with code & documentation



Structural Engineering Tools

- **Handcalcs**: Format calculations as if done by hand using latex
- **OpenSeesPy**: Python wrapper to *OpenSees* finite element analysis
- **Anastruct**: Plane frame structural analysis
- **sectionproperties**: Calculate properties of arbitrary sections
- **concreteproperties**: Stress & moment-curvature analysis of concrete sections
- **PyEMA**: Experimental Modal Analysis
- **PyFRF**: Frequency Response Functions
- . . . many many more

Laboratory Tools

- **npTDMS**: Read TDMS files created by LabView or NI DAQs
- **PyDIC**: Digital Image Correlation analysis
- **Rattlesnake**: Vibration controller by Sandia Labs
- **PyExSi**: Excitation signals for structural dynamics experiements
- **speckle_pattern**: Speckle generator for DIC
- . . . many many more

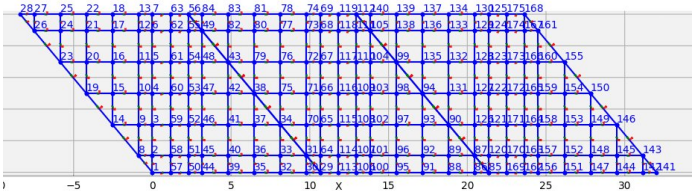
Packages from Monash Smart Structures

- **ospgrillage**: Bridge deck grillage analysis
- **PySTRA**: Structural reliability analysis (FORM, SORM, etc)
- **calabru**: Structural model updating (sensitivity & bayesian)
- **PyCBA**: Continuous beam analysis
- **ospgrid**: Simple grid analysis (mainly for teaching)
- **pyHSI**: Human-structure interaction (MF, MM, MSMD in FE, MA)
- . . . with more to come

ospgrillage

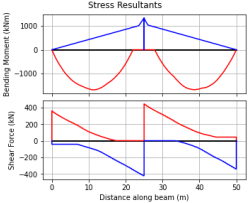
Capabilities:

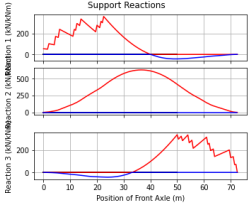
- Shell, beam, links
- Oblique, orthogonal, skew
- Multi-span options
- Curved decks
- Point and patch loads
- Moving loads

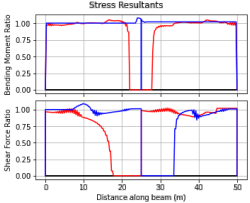


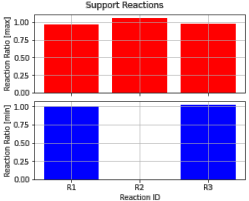
Ngan & Caprani, (2022). `ospgrillage`: A bridge deck grillage analysis preprocessor for `OpenSeesPy`. *Journal of Open Source Software*, 7(77), 4404, 10.21105/joss.04404

PyCBA

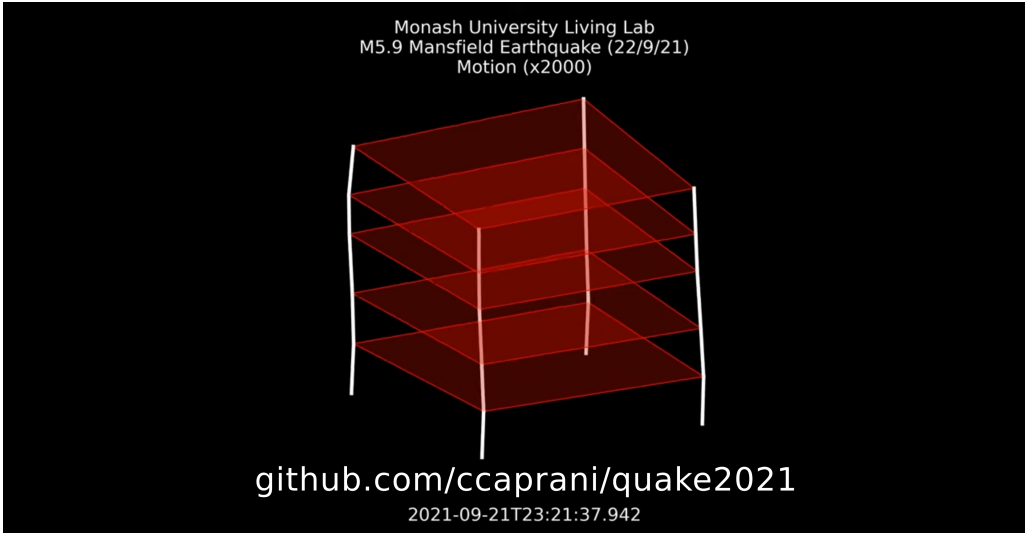

Stress Resultants
Bending Moment (kNm)
Shear Force (kN)
Distance along beam (m)


Support Reactions
Reaction 1 (kN/kNm)
Reaction 2 (kN/kNm)
Reaction 3 (kN/kNm)
Position of Front Axle (m)


Stress Resultants
Bending Moment Ratio
Shear Force Ratio
Distance along beam (m)


Support Reactions
Reaction Ratio [max]
Reaction Ratio [min]
R1
R2
R3
Reaction ID

Case Study


Monash University Living Lab
M5.9 Mansfield Earthquake (22/9/21)
Motion (x2000)
github.com/ccaprani/quake2021
2021-09-21T23:21:37.942

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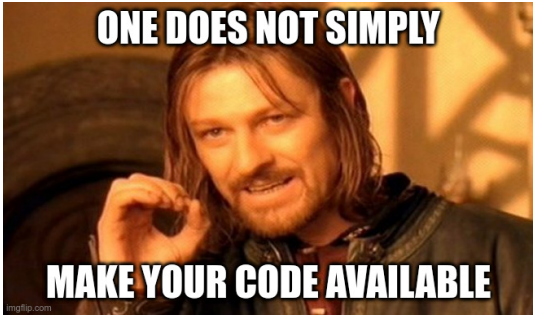
We need our research to have more impact!
Open-source it
Provide docs
But they'll steal our ideas
imgflip.com

Opportunity

- Stand on the shoulders of others (often giants!)
- Be at the cutting edge sooner
- Ensure your work has real impact

Github

- Proper version control and code history
- `pip`: make it easily installable
- `github pages`: make it easy to use



Acknowledgements

Some ideas here have been borrowed from Jake VanderPlas' PyCon 2017 talk: *The Upexpected Effectiveness of Python in Science*

Thank you!