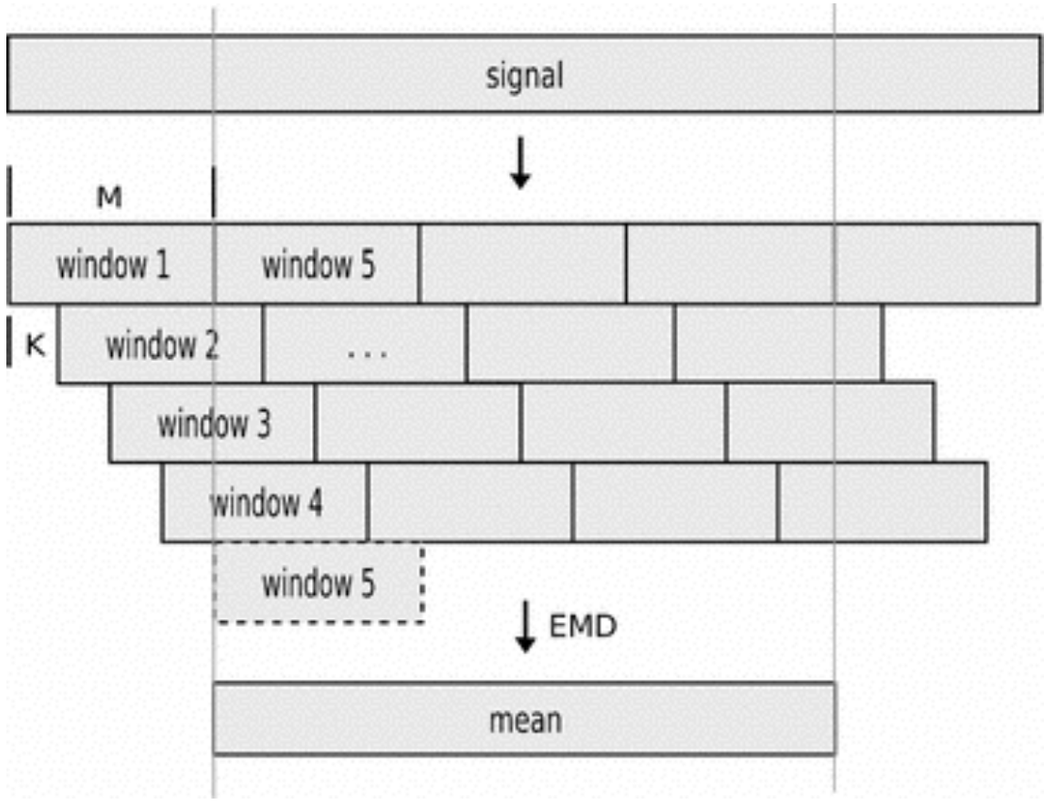
EtaGen v0.1

Edwin J. Son (NIMS)

Boot Camp Hands-on Tutorial on Dec. 9

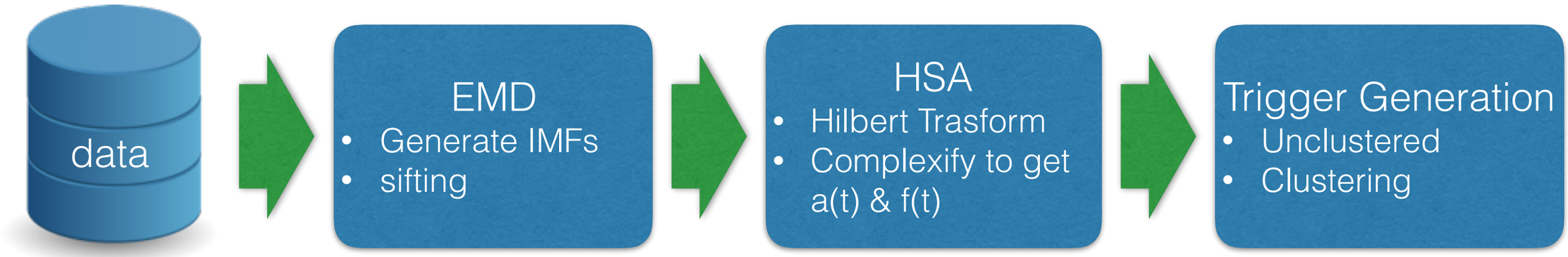
What is EtaGen

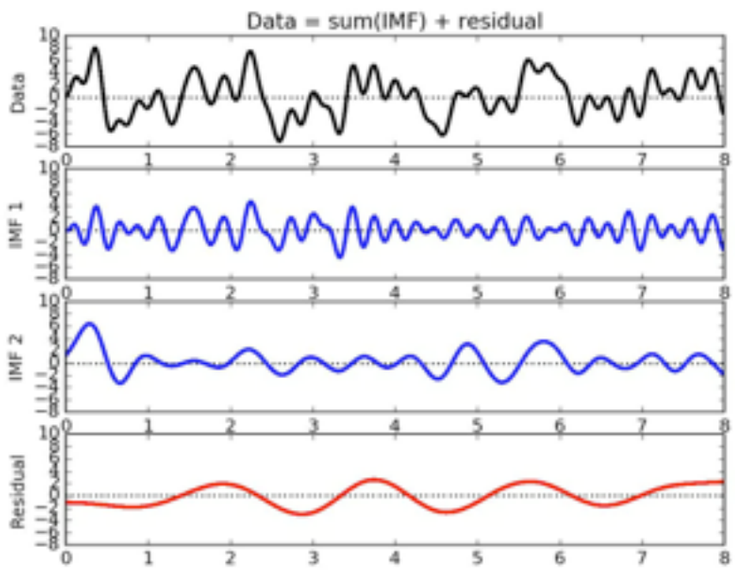
- EtaGen is an event trigger generator based on Hilbert-Huang Transform (HHT)
- HHT = Empirical Mode Decomposition (EMD) + Hilbert Spectral Analysis (HSA) (for a review, see Huang et al., Rev. Geophys. 2008)
- To reduce computing cost, we are using weighted sliding EMD (wSEMD) instead of Ensemble EMD (EEMD)
- Hopefully, EtaGen will be soon distributed to public

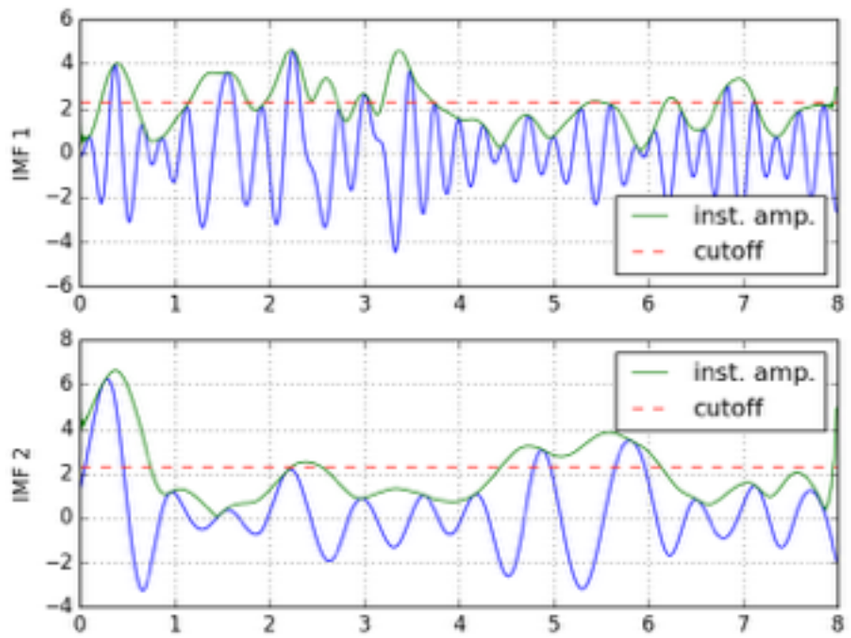


wSEMD Concept Image
(credit: R. Faltermeier et al. 2011)

How it works


data
EMD
• Generate IMFs
• sifting
HSA
• Hilbert Trasform
• Complexify to get a(t) & f(t)
Trigger Generation
• Unclustered
• Clustering


Data = sum(IMF) + residual
Data
IMF 1
IMF 2
Residual

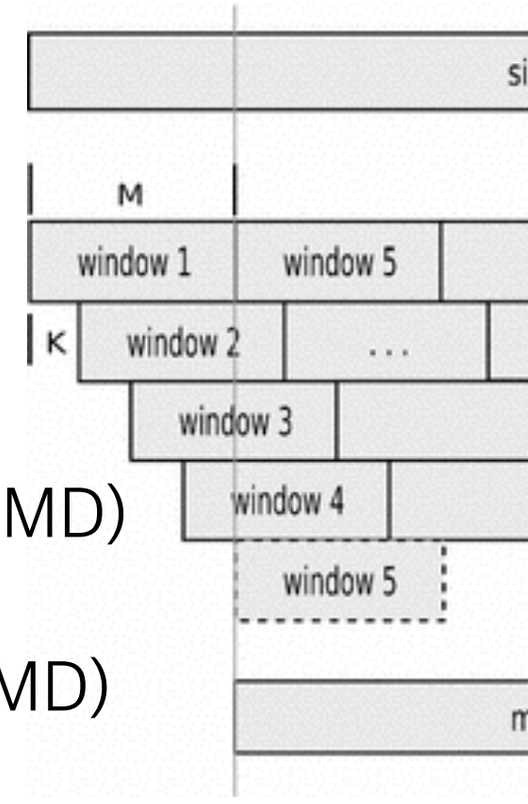

IMF 1
inst. amp.
cutoff
IMF 2
inst. amp.
cutoff

Initialize an instance

- import etagen as etg
- h = etg.etagen(data, fsr=1.0, start_time=0.0)
  - h: an instance of etagen class
  - data: input data which is assumed to be whitened (stored in h.data)
  - fsr: sampling freqeuncy. If omitted, fsr=1.0 by default (stored in h.fsr)
  - start_time: start time of data in sec. If omitted, start_time=0.0 by default (stored in h.start_time)

Set Parameters for EMD or wSEDM

- h.set_emd_param(num_imfs=0, num_sifts=15, S_number=0, emd_size=2048, num_seg=8, w_type=etg.kernel.SIN_KERNEL)
  - num_imfs: Number of IMFs (stored in h.nimfs)
  - num_sifts: Maximum number of siftings
  - S_number: Criterion to stop sifting, $|N_{ext} - N_{zero}| \leq S$
  - emd_size: Number of samples in each segment (for wSEMD)
  - num_seg: Number of segments to average out (for wSEMD)
  - w_type: Type of weighting kernel (for wSEMD)



EMD or wSEMD

- You can use either emd() or wsemd() to decompose data into IMFs (stored in h.imfs)
- h.emd()
  - No arguments required
- h.wsemd()
  - No arguments required

Hands-on example #1

- Get the environment in the seikai server:

```
$ source ~detchar/initHasKAL.bashrc              # HasKAL environment
$ source ~eddy/bootcamp/etc/etagen-env.sh        # EtaGen environment
$ pip2.7 install --user numpy matplotlib scipy # required python module
```

- Run IPython:

```
$ ipython
Python 2.7.11 (default, Dec  7 2015, 11:22:37)
Type "copyright", "credits" or "license" for more information.

IPython 5.1.0 -- An enhanced Interactive Python.
?         -> Introduction and overview of IPython's features.
%quickref -> Quick reference.
help      -> Python's own help system.
object?   -> Details about 'object', use 'object??' for extra details.

In [1]:
```

Hands-on #1 (cont'd)

- Import modules:

```
In [1]: import numpy as np

In [2]: from etagen import etagen
```

- Get IMFs of Gaussian random noise via wSEMD:

```
In [3]: Fs = 1024

In [4]: noise = np.random.randn(65536)

In [5]: h = etagen(noise, fsr=Fs)

In [6]: h.set_emd_param(num_imfs=8, num_seg=4)

In [7]: h.wsemd()

In [8]: print "# of IMFs: {0}, # of NaNs: {1}".format(h.nimfs,
h.imfs[np.isnan(h.imfs)].shape[0])
# of IMFs: 8, # of NaNs: 0
```

HSA

- h.hilbert(filter_length=128, stride=256)
  - filter_length: Length of FIR filter for DHT
  - stride: Number of samples to estimate instantaneous frequency
  - Hilbert transformed IMFs will be stored in h.hht
  - Instantaneous amplitudes and frequencies of IMFs will be stored in h.insa and h.insf

Unclustered Triggers

- h.get_utriggers(snr_th=3, stride=0, overlap=0, skip=0)
  - snr_th: SNR threshold to generate triggers (stored in h.min_snr)
  - stride: Number of samples in a segment used to estimate background noise
  - overlap: Number of samples overlapped between segments
  - skip: Number of skipped samples in the edge of data
  - Generated triggers will be stored in h.utrgs

Clustered Triggers

- h.get_triggers(snr_th=10, t_tolerance=0.0, f_tolerance=0.0, u_snr_th=3)
  - snr_th: SNR threshold to generate trigger clusters (stored in h.snr_threshold)
  - t_tolerance: time tolerance for clustering [sec]
  - f_tolerance: frequency tolerance for clustering [ratio]
  - u_snr_th: SNR threshold for unclustered triggers to be clustered (stored in h.u_snr_threshold)
  - Clustered triggers will be stored in h.trgs

Hands-on #1 (cont'd)

- Get triggers:

```
In [9]: h.hilbert()

In [10]: h.get_triggers(snr_th=5)
Generating triggers with 3-snr threshold in segments of length 65536, overlapping 0
samples and skipping 0 samples from boundaries...
... generated 3104 trigger event(s)
Clustering triggers of u_snr > 3 with time tolerance=0.0, frequency tolerance=0.0 and
dropping clusters of snr < 5...
... generated 583 trigger cluster(s)
```

- Get some infos. of the max_snr trigger:

```
In [11]: indx = h.trgs['snr'].argmax()

In [12]: print "MAX SNR: {0:.2f} at {1:.2f} sec. and {2:.2f} Hz".format(h.trgs[indx]
['snr'], h.trgs[indx]['p_time'], h.trgs[indx]['p_freq'])
MAX SNR: 15.92 at 17.85 sec. and 222.37 Hz
```

Hands-on example #2

- Add a sine-Gaussian signal over the noise and generate triggers:

```
In [13]: from bootcamphelper import sineGaussian

In [14]: signal_time = np.linspace(-1.5, 1.5, 3*Fs, endpoint=False)

In [15]: signal = 3 * sineGaussian(50, 100, signal_time)

In [16]: data = noise.copy()

In [17]: data[30*Fs:33*Fs] += signal

In [18]: g = etagen(data, Fs)

In [19]: # Follow the procedure of hands-on example #1 by using “g” instead of “h”
```

- Following the procedure of #1, you may see the loudest trigger near 31.5 sec.

A script for KAGRA data in the seikai server

- A script for KAGRA data (location: ~eddy/bootcamp/bin/kagetagen.py):

```
$ kagetagen.py --out-dir output --gps-start-time 1145621536 \
> --gps-end-time 1145621600 --channel K1:LSC-MICH_CTRL_CAL_OUT_DQ \
> --sampling-frequency 16384 --emd-method wsemd --number-of-imfs 10 \
> --snr-threshold 5.5 /data/kagra/raw/full/K-K1_C-1145621[56]*.gwf
```

- This script use `FrameDataDump` in `HasKAL` to extract data

- You don't need to know Python to run this script

- Hands-on example #3: find triggers in KAGRA data of channel `K1:LSC-MICH_CTRL_CAL_OUT_DQ` from `1145621536` to `1145621568` by using the above script

Some options for the script

- -h, --help
  - show the help message
- --quiet
  - reduce stdout messages
- -o OUTDIR, --out-dir OUTDIR
  - Directory path where output files will be located

- -s GPS_START_TIME, --gps-start-time GPS_START_TIME
  - GPS start time of KAGRA data in sec.
- -e GPS_END_TIME, --gps-end-time GPS_END_TIME
  - GPS end time of KAGRA data in sec.
- -c CHANNEL, --channel CHANNEL
  - Channel name
- -f FSR, --sampling-frequency FSR
  - Sampling frequency in Hz

- -m {emd,wsemd}, --emd-method {emd,wsemd}
  - EMD method
- -I NUM_IMFS, --number-of-imfs NUM_IMFS
  - Number of IMFs
- -T SNR, --snr-threshold SNR
  - SNR threshold for trigger generation
- -G, --plot-trigger
  - If set, trigger distribution will be plotted

Trigger file from the script

- Filename convention:
  output/{channel name}/TRG_{channel name}-{start time}-{duration}.txt

- An example of trigger file:

```
# s_time      e_time  c_time  c_freq  c_energy      p_time  p_freq  p_amp   p_imf_idx
p_snr   f_min   f_max   npts    snr

1145621549.39   1145621549.64   1145621549.5    32.0978011138   0.79732707563   1145621549.46
30.8421454391   0.90591291609   6       18.0275844935   5.35106740598   126.819252762   6
24.2931992713

1145621555.14   1145621555.23   1145621555.17   168.530469161   0.435129056977  1145621555.16
349.234736403   0.759307323296  3       3.96260428079   39.0329795337   405.324007045   5
7.50064722872

1145621553.49   1145621553.72   1145621553.56   96.3266691716   0.225746843968
1145621553.51   90.8877928668   0.199682669844  5       3.17691573596   28.5208729623
271.918467305   6       7.39301000967
```

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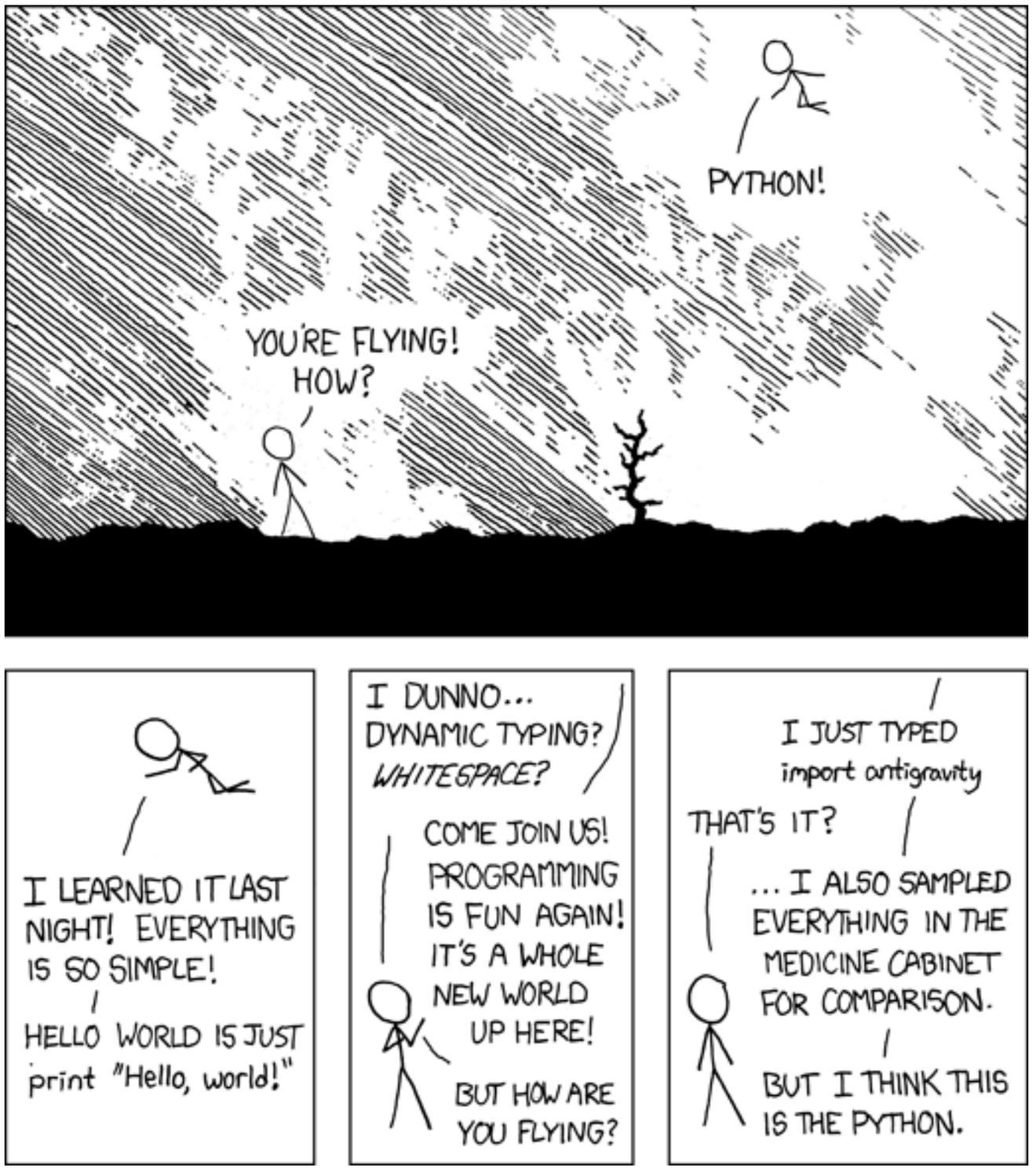
Thank you



[https://xkcd.com/353/]

Scatter plot of triggers