nitime

Time-series analysis for fMRI data

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Outline

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- Scientific motivation

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- The `nitime` software library

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- The `nitime` software library
- A simple example: coherence

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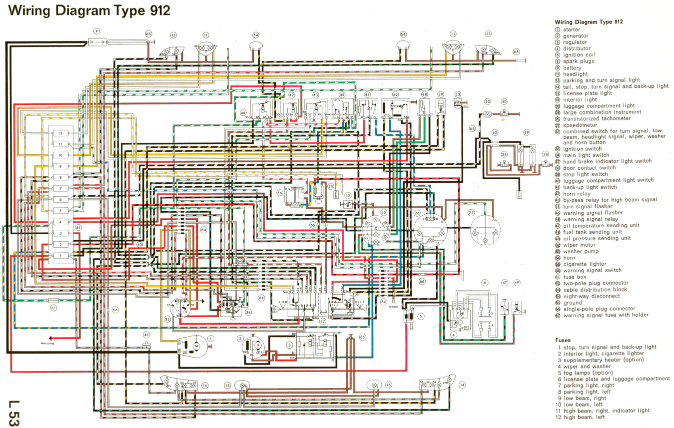
- The `nitime` software library
- A simple example: coherence
- A scientifically interesting example

Task-specific networks

One of the goals of contemporary neuroscience is to delineate task-specific networks in the brain

The wiring diagram



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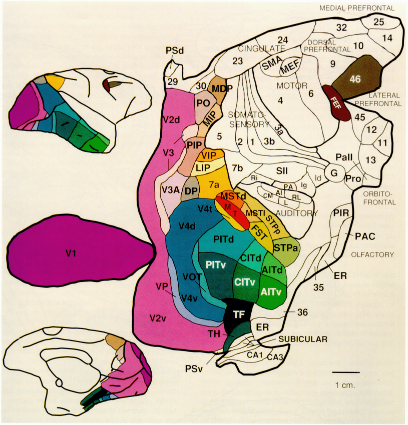
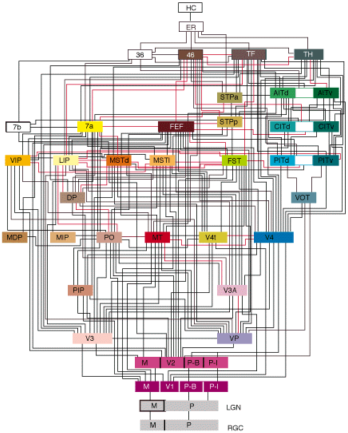


Felleman and Van Essen (1991)

The wiring diagram



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Task-specific networks

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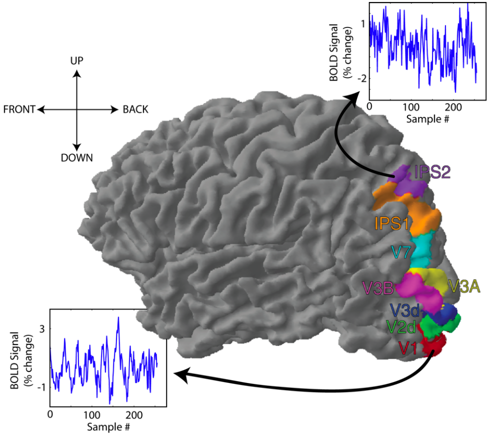
Time-series in fMRI data



Nitime

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- Software library for the analysis of time-series from neuroscience data

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- Written in Python

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- `http://nipy.org/nitime`

nitime components:

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- nitime.timeseries

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- nitime.utils

TimeSeries example:

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```
>>> import nitime.timeseries as ts
>>> t1 = ts.TimeSeries(data=[1,2,3,4],
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```

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>>> import nitime.timeseries as ts
>>> t1 = ts.TimeSeries(data=[1,2,3,4],
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>>> t1.time
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UniformTime([ 0. ,  1.5,  3. ,  4.5],
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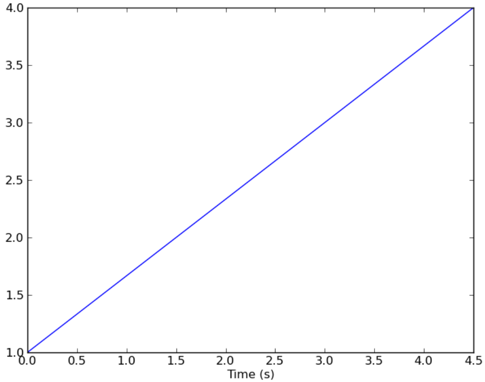
>>> t1.sampling_rate
0.666666666667 Hz
```

Vizualization

Vizualization

```
>>> import nitime.viz as viz
>>> viz.plot_tseries(t1)
```

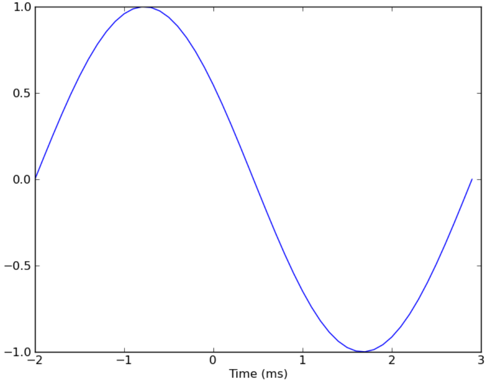
Vizualization



Vizualization

```
>>> t2 = ts.TimeSeries(data=np.sin(
                        np.linspace(0,2*np.pi)),
                        sampling_interval=0.1,
                        t0=-2,
                        time_unit='ms')
>>> viz.plot_tseries(t2)
```

Vizualization



nitime.algorithms

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- Provides a functional interface based on numpy arrays

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`nitime.algorithms`

- Provides a functional interface based on numpy arrays
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- `filter`
- `spectral`
- `autoregressive`
- These implementations accept arrays as their inputs, not `TimeSeries`!

Example: univariate analysis

Example: univariate analysis

```
>>> noise = 0.5
>>> t = np.linspace(0,8*pi,1024)

>>> x =  (np.sin(5*t) + np.sin(1.33*t) +
     noise*np.random.randn(t.shape[-1]))

>>> y =  (np.sin(5*t + pi/4) +
          np.sin(1.33*t-pi/2) +
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>>> t3 = ts.TimeSeries(np.vstack([x,y]),
                    sampling_rate=np.pi)
```

Example: univariate analysis

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>>> noise = 0.5
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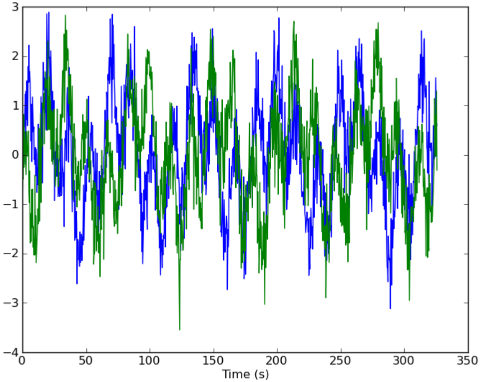
>>> t3 = ts.TimeSeries(np.vstack([x,y]),
                  sampling_rate=np.pi)

>>> viz.plot_tseries(t3)
```

Time-series



Univariate analysis: spectral analysis

```
>>> import nitime.algorithms as alg
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>>> method = {'this_method':'welch',
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```

Univariate analysis: spectral analysis

```
>>> import nitime.algorithms as alg

>>> method = {'this_method':'welch',
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>>> f, c = alg.get_spectra(t3.data,method=method)
```

Univariate analysis: spectral analysis

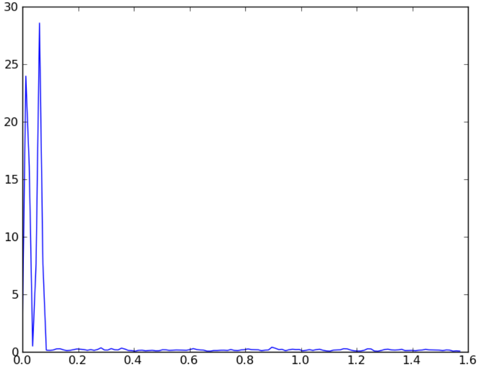
```
>>> import nitime.algorithms as alg

>>> method = {'this_method':'welch',
              'Fs':np.pi,
              'NFFT':256}

>>> f, c = alg.get_spectra(t3.data,method=method)

>>> import matplotlib.pylab as pl
>>> plt.plot(f, c[0,0])
```

Univariate analysis: spectral analysis



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- 'Knows' about `TimeSeries` objects and accepts them as inputs
- `coherence`
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- `normalization`
- `snr`
- `spectral`

Bivariate analysis 1: cross-correlation

$$Rxy(\tau) = \sum_{i=0}^{T} x(t) y(t+\tau)$$

Bivariate analysis 1: cross-correlation

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```
>>> import nitime.analysis as nta
```

Bivariate analysis 1: cross-correlation

```
>>> import nitime.analysis as nta

>>> XC = nta.CorrelationAnalyzer(t3)
```

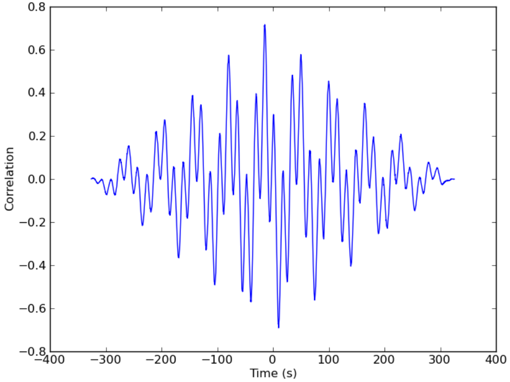
Bivariate analysis 1: cross-correlation

```
>>> import nitime.analysis as nta

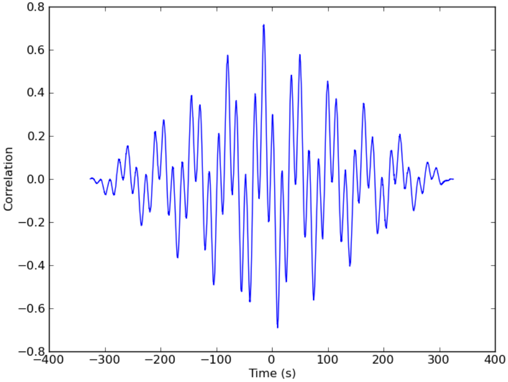
>>> XC = nta.CorrelationAnalyzer(t3)

>>> viz.plot_xcorr(XC.xcorr_norm,[[0,1]])
```

Bivariate analysis 1: cross-correlation



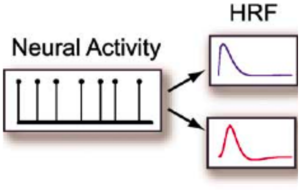
Bivariate analysis 1: cross-correlation



$r_{xy} = 0.25$

Why should we care?

Hemodynamic delays



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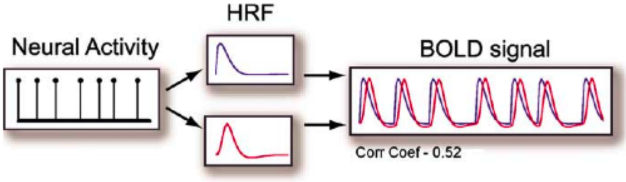


Coherency

A spectral analog of correlation

Coherency

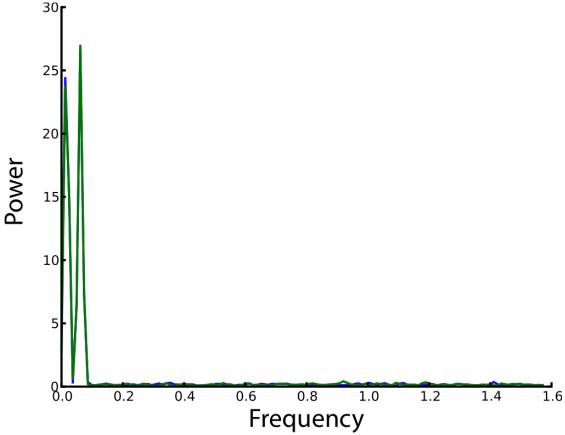
$$C_{xy}(\omega) = \frac{f_{xy}(\omega)}{\sqrt{f_{xx}(\omega) f_{yy}(\omega)}}$$

Coherency

$$C_{xy}(\omega) = \frac{f_{xy}(\omega)}{\sqrt{f_{xx}(\omega)f_{yy}(\omega)}}$$

Where, f_{xy} is the cross-spectral density and f_{xx} is the PSD of x

Coherency



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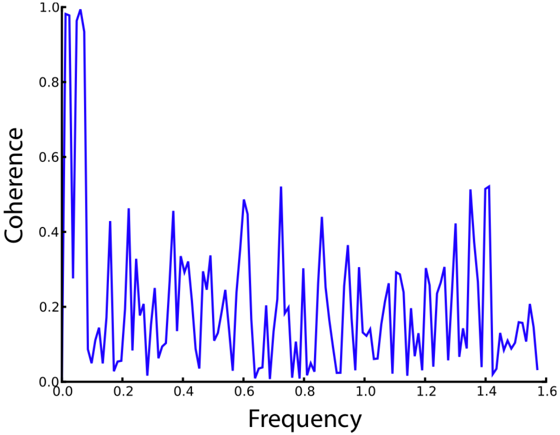
Ranges from 0 to 1

Coherence



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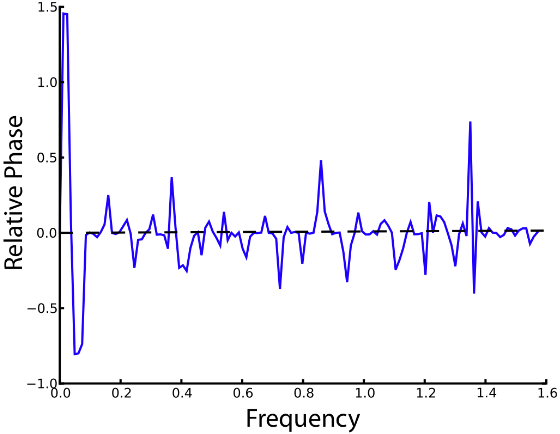
Ranges from $-\pi$ to π

Phase

```
>>> plt.plot(C.frequencies, C.phase[0,1])
```

Phase


1.5
1.0
0.5
0.0
−0.5
−1.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
Relative Phase
Frequency

Not surprising

```
>>> noise = 0.5
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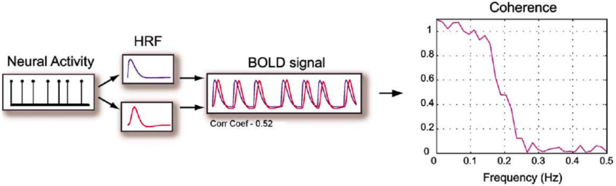
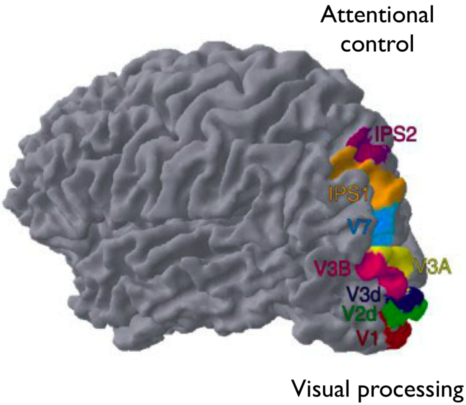
Coherency



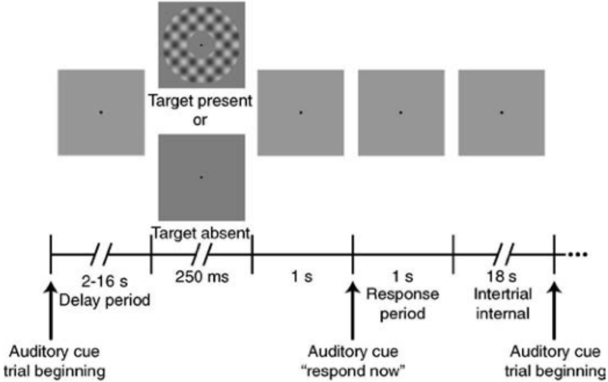
Sun et al. (2004,2005)

Using coherency to study task-related networks



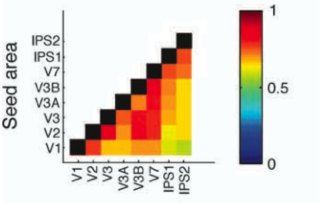
Lauritzen et al. (2009)

Covert attention task



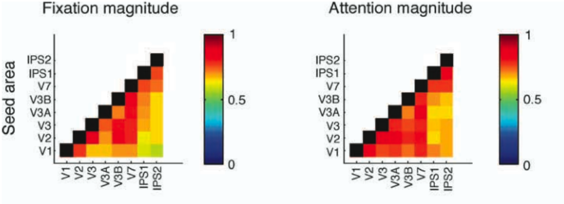
Lauritzen et al. (2009)

Baseline coherence



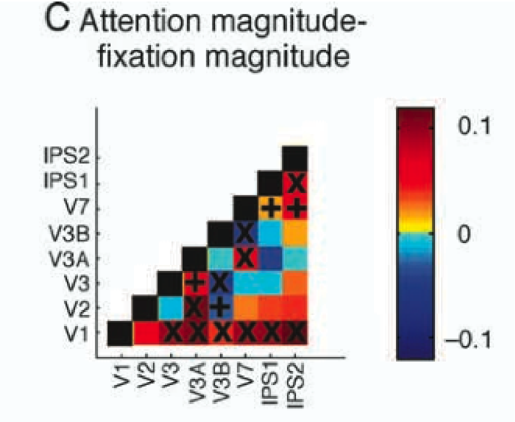
Lauritzen et al. (2009)

Attention coherence



Lauritzen et al. (2009)

Difference in coherence



Lauritzen et al. (2009)

Time delay

The time-delay between two time-series can be calculated from the phase delay

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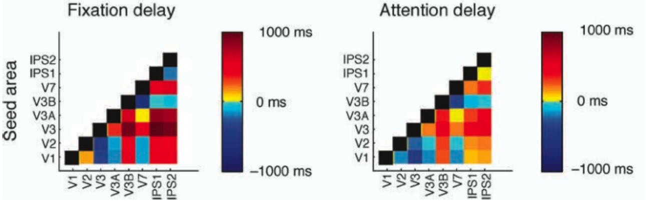
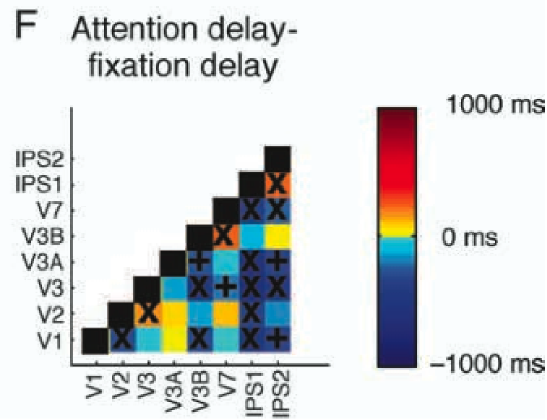
$$\Delta t(\omega) = \frac{\phi(\omega)}{2\pi\omega}$$

Time delay



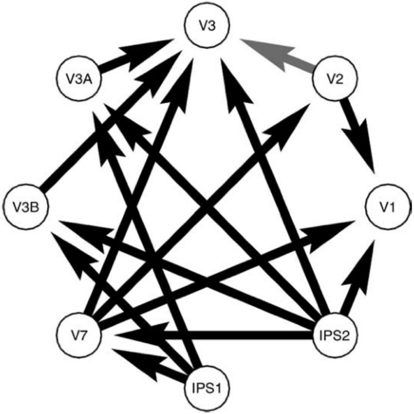
Lauritzen et al. (2009)

Delay difference



Lauritzen et al. (2009)

Task-related network changes:



Lauritzen et al. (2009)

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- Overcomes some of the pitfalls of 0-order correlation
- But - when used for fMRI need to pay attention to:
- Baseline connectivity
- Confounds due to HRF differences

More examples

http://nipy.org/nitime/examples

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Summary: `nitime`

- `nitime` provides tools for representing and visualizing time-series and derived quantities
- Implements several univariate and bi-/multi-variate algorithms for time-series analysis
- Allows for flexible use: choose the `analysis` module if you prefer a more stream-lined interface to the algorithms
- Or the `algorithms` module if you prefer more customability

Stay tuned

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Thanks!

Thanks!

Fernando Perez

Mike Trumpis

Kilian Koepsell

Paul Ivanov

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Fernando Perez
Mike Trumpis
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The NIPY developers
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