NetSci
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EEGNet
Brain functional network mapping

A probabilistic inference approach to brain network construction from data

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Road map

- Network construction with probabilistic inference.
- Motivation.
- Development framework.

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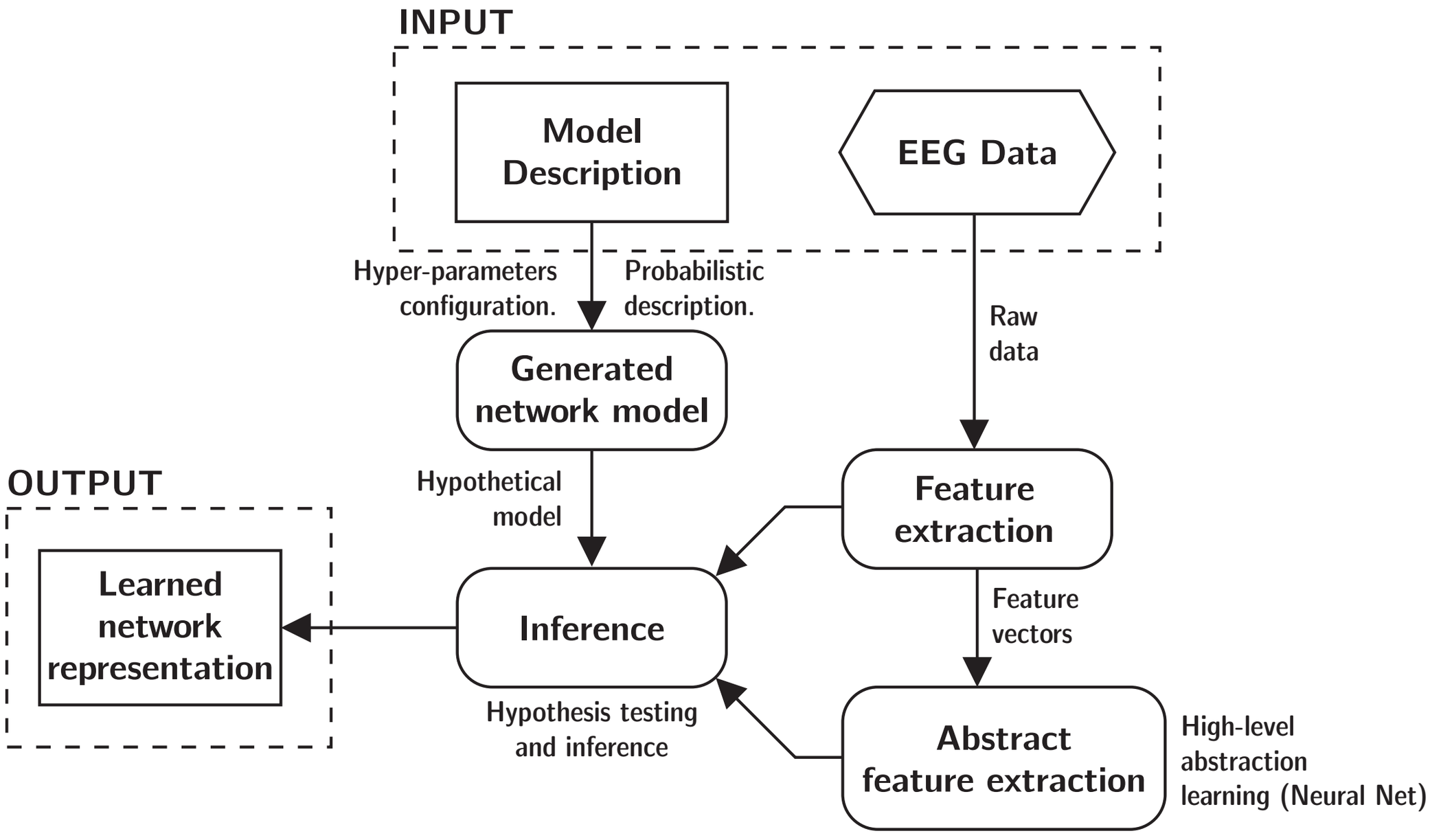
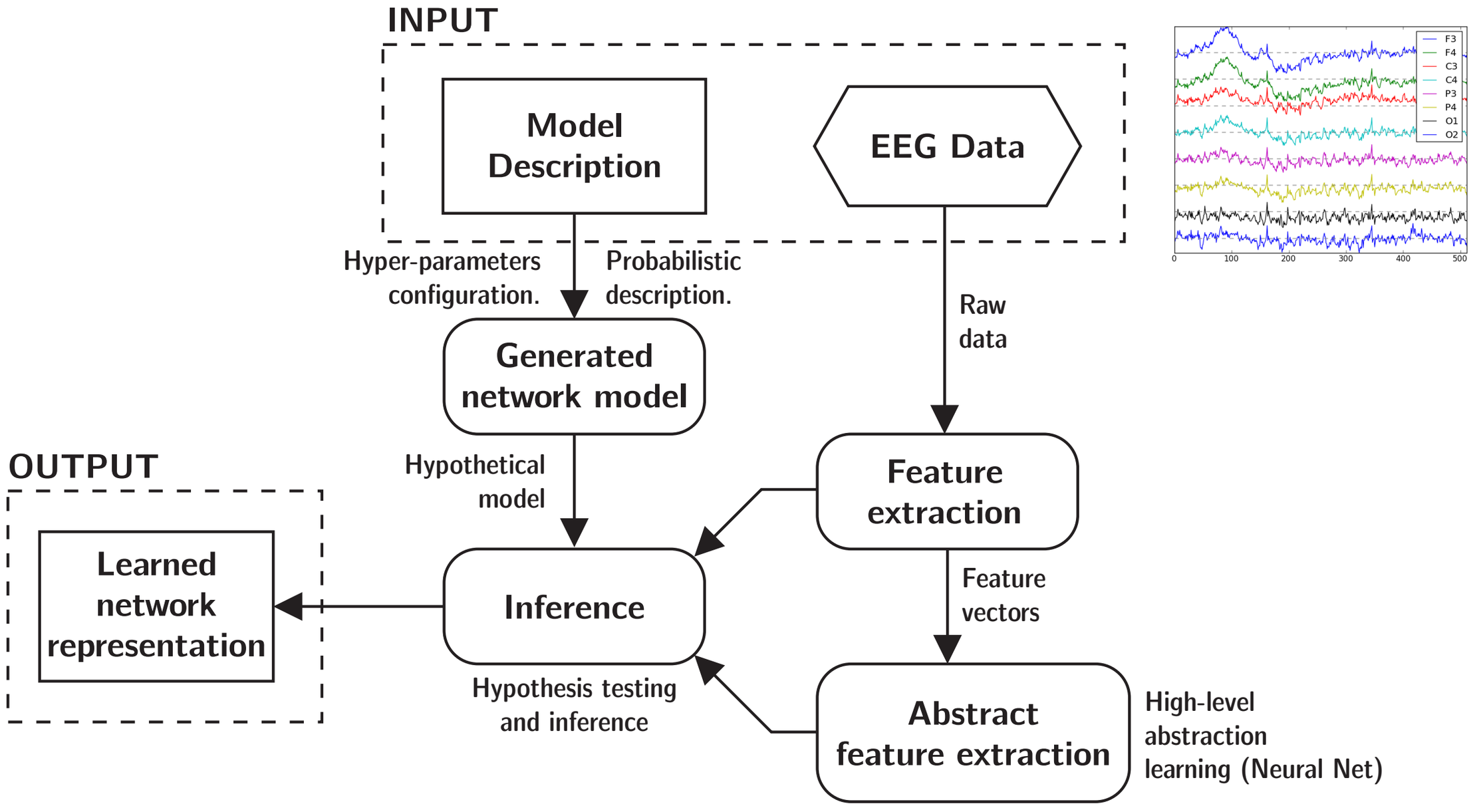
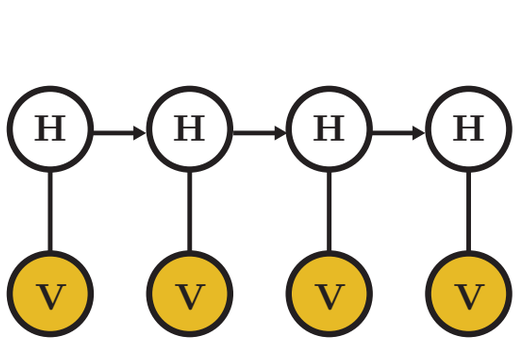
Network construction by probabilistic model

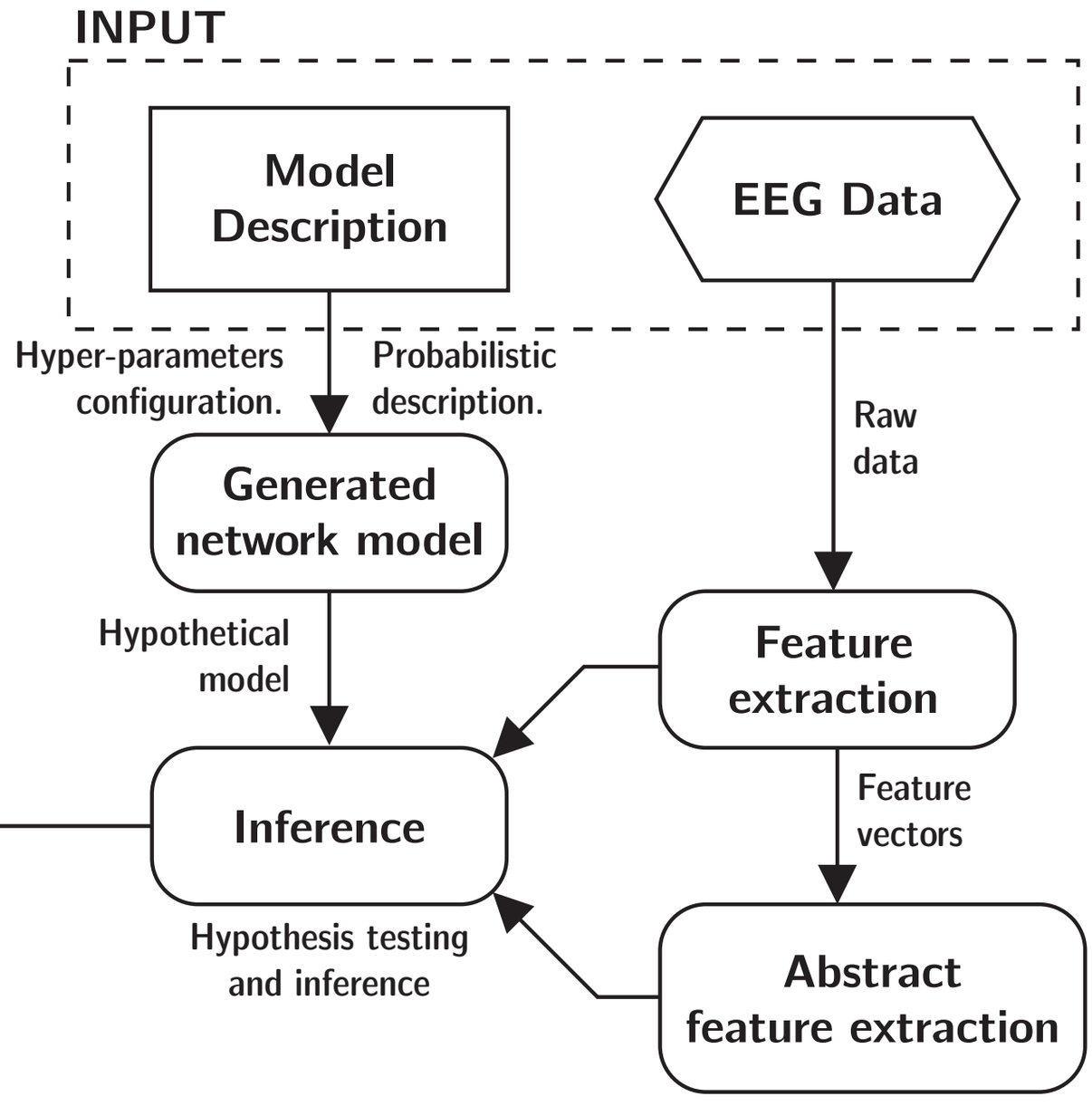


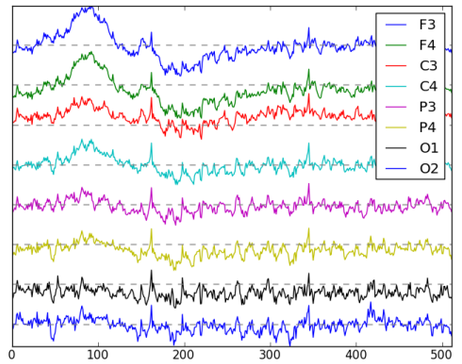
Network construction by probabilistic model



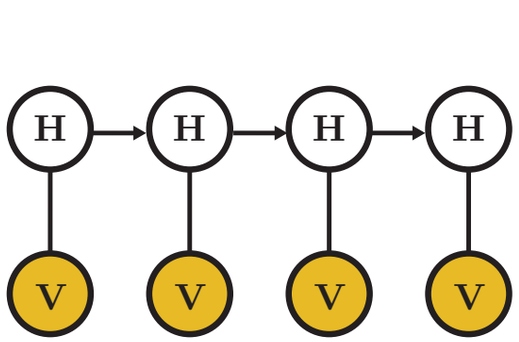
Network construction by probabilistic model







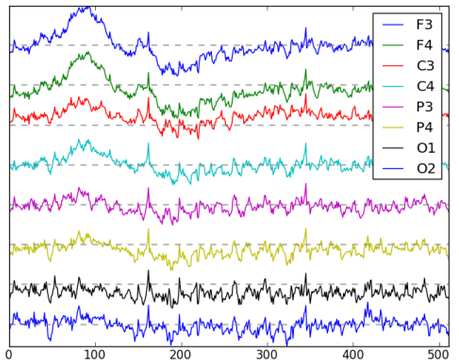
Network construction by probabilistic model



INPUT

Model Description

EEG Data



Hyper-parameters configuration.

Probabilistic description.

Generated network model

Raw data

Feature extraction

Hypothetical model

OUTPUT

Learned network representation

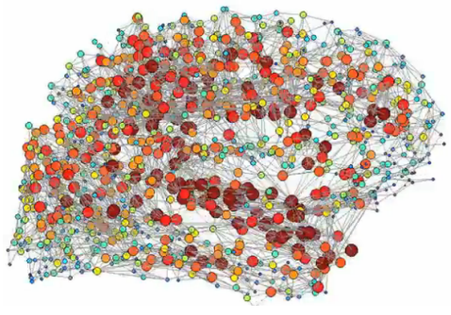
Inference

Feature vectors

Hypothesis testing and inference

Abstract feature extraction

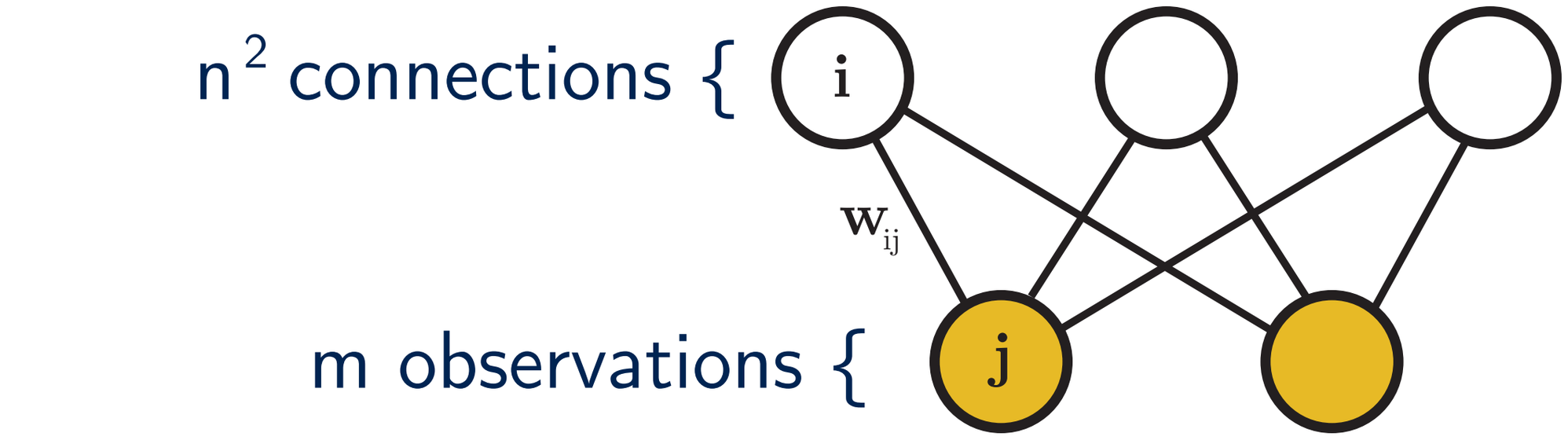
High-level abstraction learning (Neural Net)



Advantages over traditional methods

Learning procedure is straight forward.

- Represented as a n x n matrix.



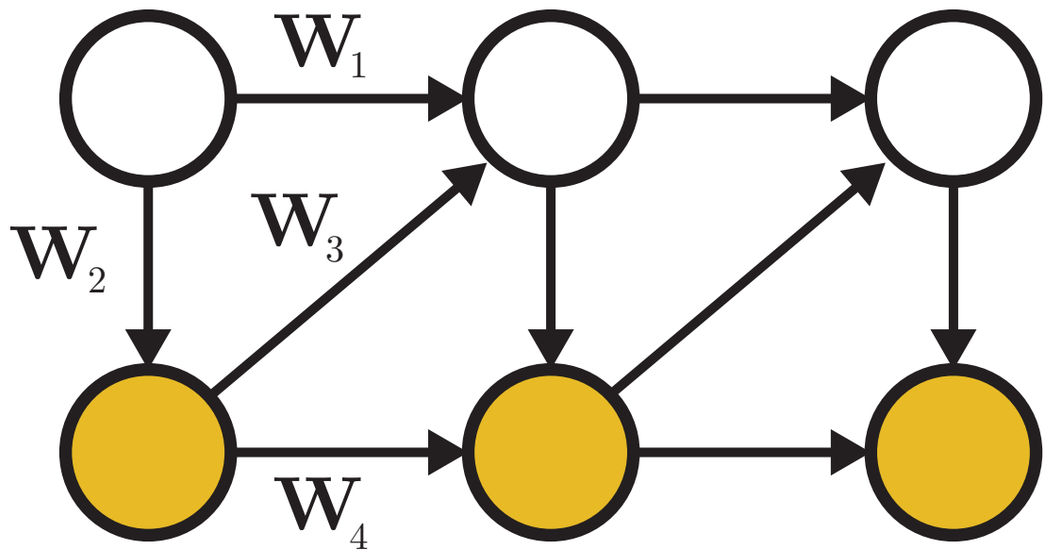
- Target distribution to learn: $P(N, \theta^H, Data)$
- Flexible model that user can defined.

[Probabilistic machine learning and artificial intelligence. Zoubin Ghahramani. Nature Vol 521, 2015.]

Advantages over traditional methods

Potential: latent representation and temporal pattern

- Represented as a n x n x T tensor.
- Temporal Sigmoid Belief Network model.



- Target distribution to learn: $P(N^T, \theta^H, Data)$

[Deep Temporal Sigmoid Belief Networks for Sequence Modeling. Zhe Gan. NIPS conference 2015.]

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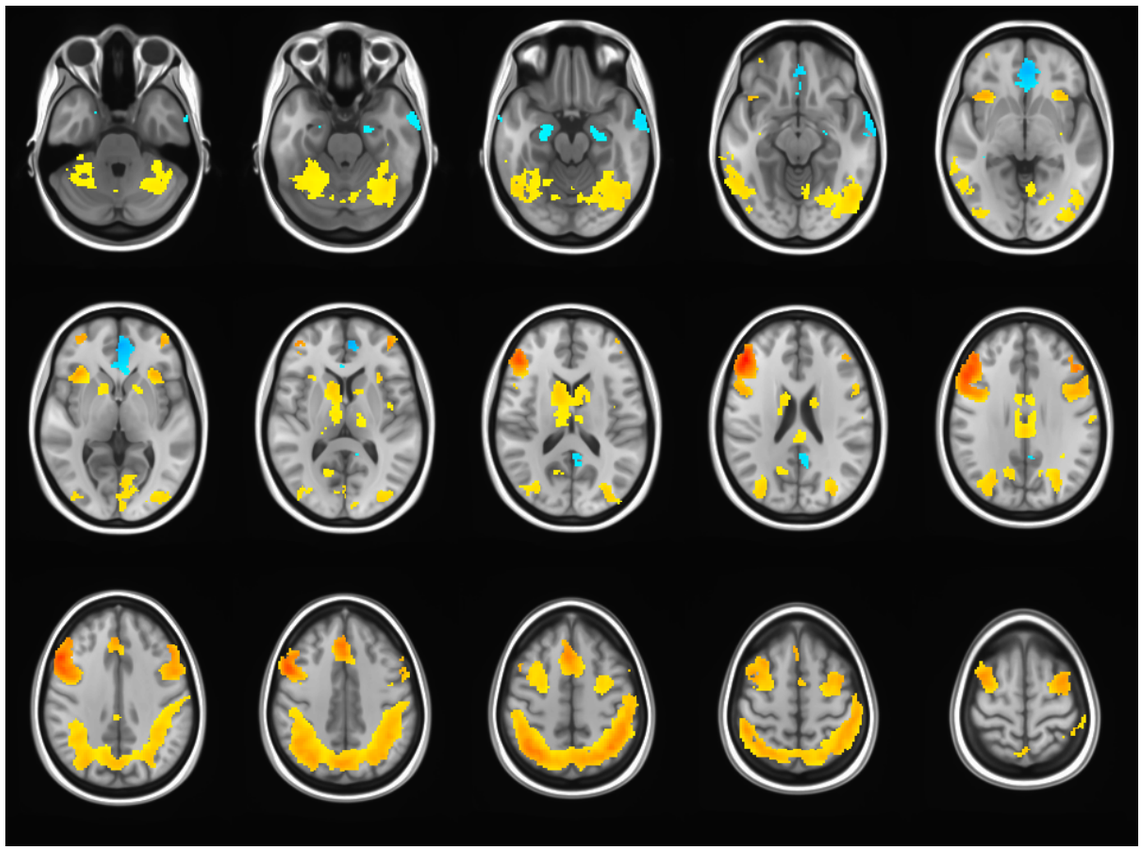
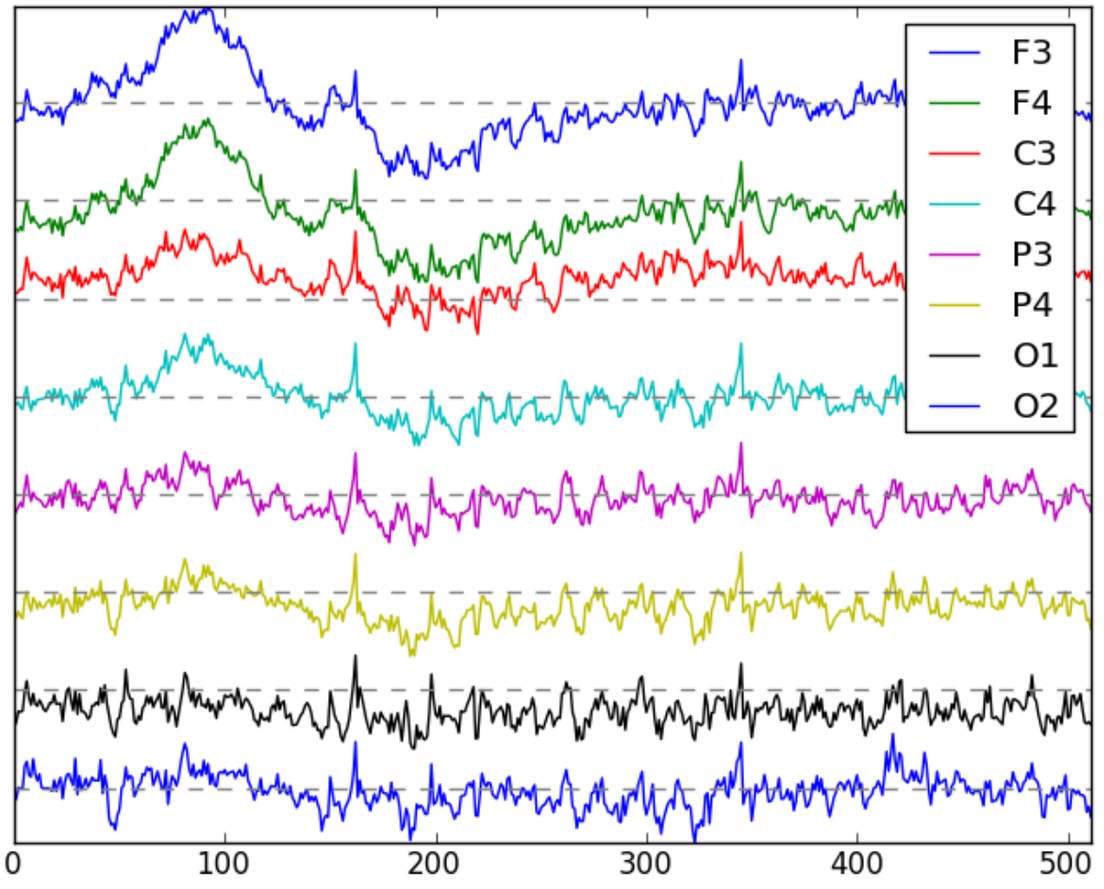
Existing methods for constructing brain network

Imaging techniques

- fMRI



- EEG



Existing methods for constructing brain network

Imaging techniques

- fMRI
  - Measure blood flow.
  - Good spatial resolution.
  - Low temporal resolution.
  - Requires expensive equipments.
- EEG
  - Measure electrical potential.
  - Low spatial resolution.
  - High temporal resolution.
  - Cheap equipments but prone to noise.

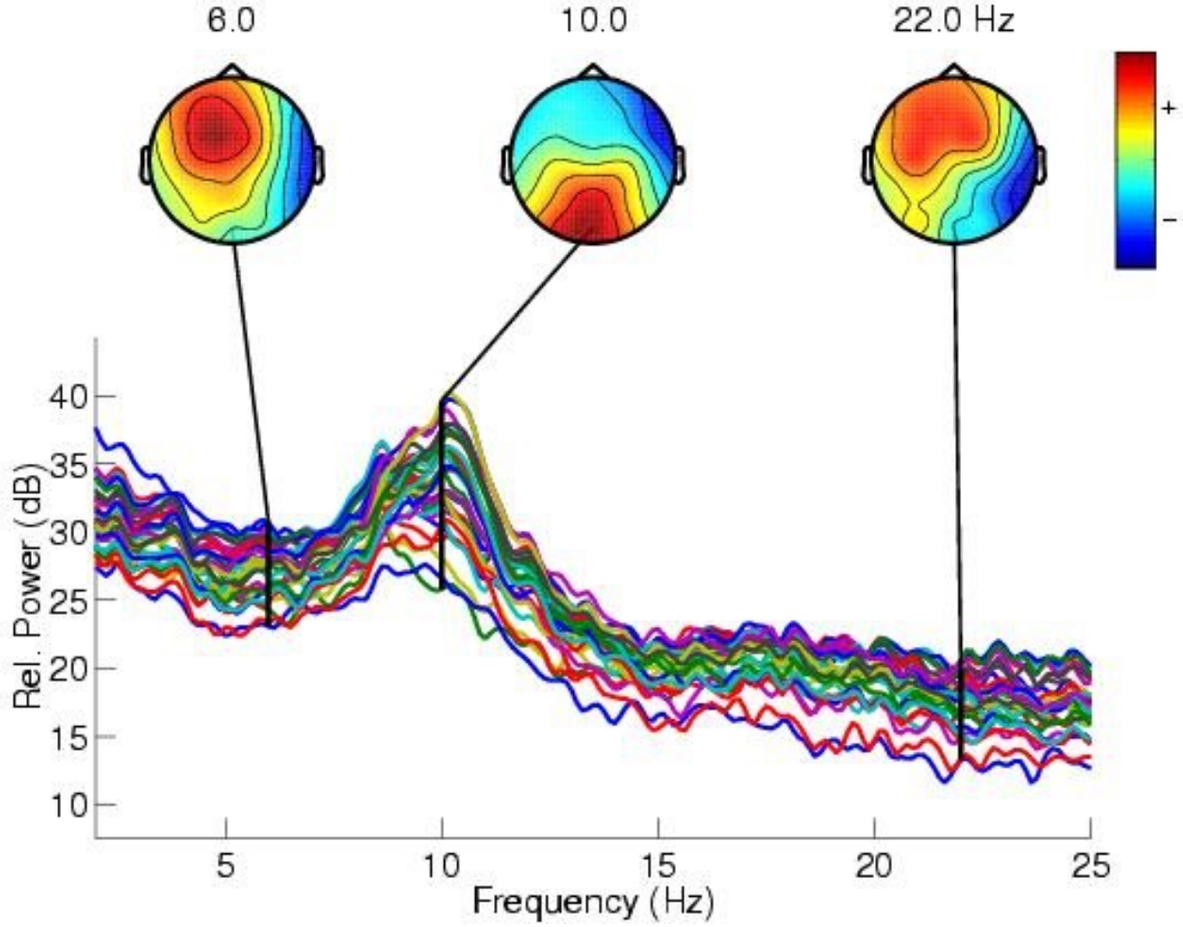
These two techniques are complementary to each other.

We want to take advantage of the EEG time series.

Existing methods for constructing brain network

Frequency-based methods

- Coherence, Non-linear coherence.



$$\kappa_{xy}^2(f) = \frac{|\langle S_{xy}(f)\rangle|^2}{|\langle S_{xx}(f)\rangle||\langle S_{yy}(f)\rangle|}$$

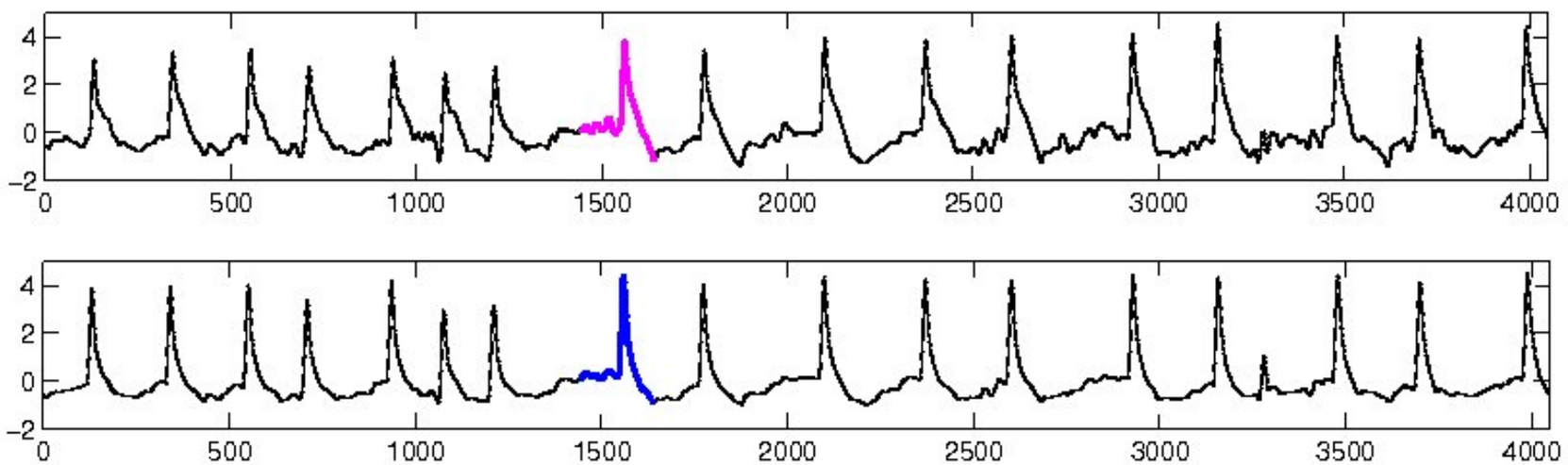
[A tutorial in connectome analysis. Markus Kaiser. NeuroImage 2011.]

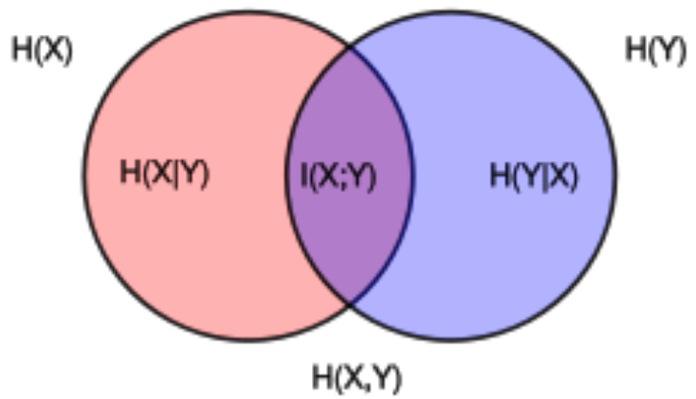
Existing methods for constructing brain network

Statistical method

- Mutual information.

$$I(X;Y) = \sum_{y \in Y} \sum_{x \in X} p(x,y) \log \left(\frac{p(x,y)}{p(x)\,p(y)} \right),$$





[Mutual information analysis of the EEG in patients with Alzheimer's disease.
Jaeseung Jeong. Clinical Neurophisiology 2011.]

Challenges with EEG data

Low spatial resolution

- 10-20 system with up to 345 electrode locations.
- Nodes in constructed network are electrodes.

High (excellence) temporal resolution

- Frequency domain and causality.
- Harnessing temporal resolution even more?
- E.g. Capturing dynamic pattern of constructed network?

Probabilistic Programming

Emerging field

- Allow fast modeling of probabilistic models.
- “Can revolutionize the industry”.

Probabilistic modeling applied to data analysis.

- Not prone to noise.
- Easier and faster model testing.

[Probabilistic machine learning and artificial intelligence. Zoubin Ghahramani. Nature Vol 521, 2015.]

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Julia programming language

High performance computing with Julia:

- Very young programming language developed at MIT.
- Rapidly growing community. (EEG.jl, brainwave.jl, EEGNet.jl)

Benefit:

- Free, fast, multiple dispatch language feature.
- Similar to Matlab / Fortran.

EEGNet framework

Flexible in modeling:

- Arbitrary voxel / atlas brain model.
- Bayesian inference (random and variational).

In development:

- Probabilistic inference framework.
- Bayesian inference (random and variational).

THANK YOU FOR LISTENING