

# Title slide

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## Outline

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### 1. Intro and motivation

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- Paradigm shift
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#### Improved hardware

There has been a recent proliferation of more rugged and durable sensor devices (e.g., fNIRS sensors) that can be used while people take part in ecologically valid activities to assess changes in neurophysiology, physiology, and behavior that correlate with cognitive state. In addition, recent advances in machine learning and modeling techniques can be used to interpret information about human states (e.g., SA) from noisy data acquired in such environments that previously was unusable.

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#### Cognition is the black box

- Improved modeling is needed
  - Use canonical engineering approach
  - Cognition acts on physiology, which is loosely tied to EEG
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#### State of the art

Recent modeling work, however, using large-scale dynamical models on the human connectome, suggests that cortical flow patterns are multistable and exhibit phase-transitions. To study such phenomena, a dynamic analysis in which no assumptions about stationarity are made, is required.

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#### Guardrails

##### What we're not saying:

- this models the brain
- this models the cellular activity

##### What we are saying

- Beam and atoms vs. brain waves and neurons
  - You can measure this dynamic signal and say something engineering about the system
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### 2. A Dynamic Systems view

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- start to introduce the structure and approach

## A canonical approach

- Have these difficult signals, nonlinear and not independent and nonstationary
- We impose this structure, consider  $A(t)$
- WHAT ARE THE MATRICES

## level is an unsolved

- realizing that the unknown input and nonlinear leaks thru
- uncertainty in  $A_m$  bc  $C_m$  would be equivalent

## Modes elegantly capture

- Giant  $(A,B,C)$  isn't useful for analysis
- modal transform is equivalent
- similarity
- yields discrete set of spatio-temporal modes which have...

# 3. Sys Id using EEG

## Datasets

- Before going further
- Looking at MODELING

## Considered algorithms

- Looked at 4 that give right structure
- For time, OMA only bc
  - classification
  - consistency
  - Numerical algorithm for Subspace State Space System Identification

## OMA theory

- **LEFT AND RIGHT SINGULAR VECTORS**
  - **FILLING IN THE DISTRIBUTION**

## Truncation

- We don't need to work with full order model
- about **40-50 modes for EEG stuff**

## EX

- see that it works

- see that it yields physically interesting models

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## 4. Modal Analysis of Brain Wave Dynamics

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Traveling vs standing

Common modes

- Find four out of 40 to be task independent

Interindividual

- use modes to id individual
- seem to act as a finger print
  - ***on our data***

BUT

- they don't match the future dynamics
- if you can go back in time, vs forward

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## 5. aUIO

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we've got a problem. address with full architecture ***somewhat removed from EEG***

Est overview

- $u$  is exogenous, ***deterministic***, something modes can't generate
- $v_x$  is a nonlinear, nonstationary
  - not restricting it to white

modeling ui

- it's too much to simply id the waveform
- select basis ***persistent*** based on engineering
- id coefs instead of waveform

arch and estimator error

- recover  $A$ 
  - update based on error
  - $\alpha$  is a filter on update
  - $\gamma_e$  is a tunable positive matrix
- know little about top

arch

- given ASD, stable transmission zeros you can find this
- notice, bound on  $v$  and  $\alpha$  define convergence rate

lil example

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## 6. Reconstructing the Brain's Unknown Input

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First things

*this really really works*

it's bc of the adaptation in the modes

details

- ui acts evenly, Linear ind and smearing
- sine cos is physically sig
- LQR gains

curious

- modes from another person
- not any hurwitz, but any eeg modes
- ***you can tolerate some slop in the modes***
  - convergence is the primary effect

classification

- We hypothesize
  - modes are correlated with human state/cognition, so
  - same state should have similar modes, so
  - you can take the average modes in a state,
  - and the estimator will perform better than the other state
- DEAP dataset and self report
- binary and interindividual

results

- on par with modern DL
- computation much less
- analysis much more
  - more than total lifetime footprint of 5 cars

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## 7. Konks

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# Ack

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