Title slide

Outline

1. Intro and motivation

- Paradigm shift
- Improved sensing, path planning, decision making
- Lots of human to computer, less computer to human
- Automation conundrum and teaming, bi-directional flow
- Are you paying attention???

Endsley quote

- Historically simulation questionnaire
- Sensors and modeling moving towards physiological measures of human state/cognition

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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

State of the art

- Nonstationary signals make the ***dynamics*** tricky
- Phase and traveling waves
- This work seeks a method to address in engineering dynamics terms
    - with eye towards cognitive outcomes

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

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2. A Dynamic Systems view

- start to introduce the structure and approach

Important EEG details

- EEG is only loosely tied to outcomes
- Linear, nonlinear, and noise
- Channel cross talk
- Variety of referencing techniques

A canonical approach

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

level is an unsolved

- We can't not know everything
- but we do
- SO
    - first identify the linear structure
    - ***around an operating point***
    - realizing that the unknown input and nonlinear leaks thru
    - uncertainty in A_m bc C_m would be equivalent

treating nonlinear

- Lots of works says this is a nonlinear nonstationary system
- We introduce a nonlinear nonstationary estimator that updates the model in real time

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...

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3. Sys Id using EEG

With that overview, how do we extract that first step, the linear operating point...

Considered algorithms

- We want to extract those ***linear*** patterns from the data
- Looked at 4 that give right structure
- For time, OMA only bc

    - classification
    - consistency
    - Numerical algorithm for Subspace State Space System IDentification

OMA theory

- A discrete time plant looks like this
- If we knew size of C and initial condition...
- So we vary the size and check SVD
    - ***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

- Remember, linear model of nonlinear system
    - Is it useful???
- Analysis

Traveling vs standing

- When do waves reach peak?
- a function of uneven damping
- negative damping
- indicates different regions doing different tasks

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

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

Est overview

- u is exogenous, ***determenistic***, 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

6. Reconstructing the Brain’s Unknown Input

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

Ack
