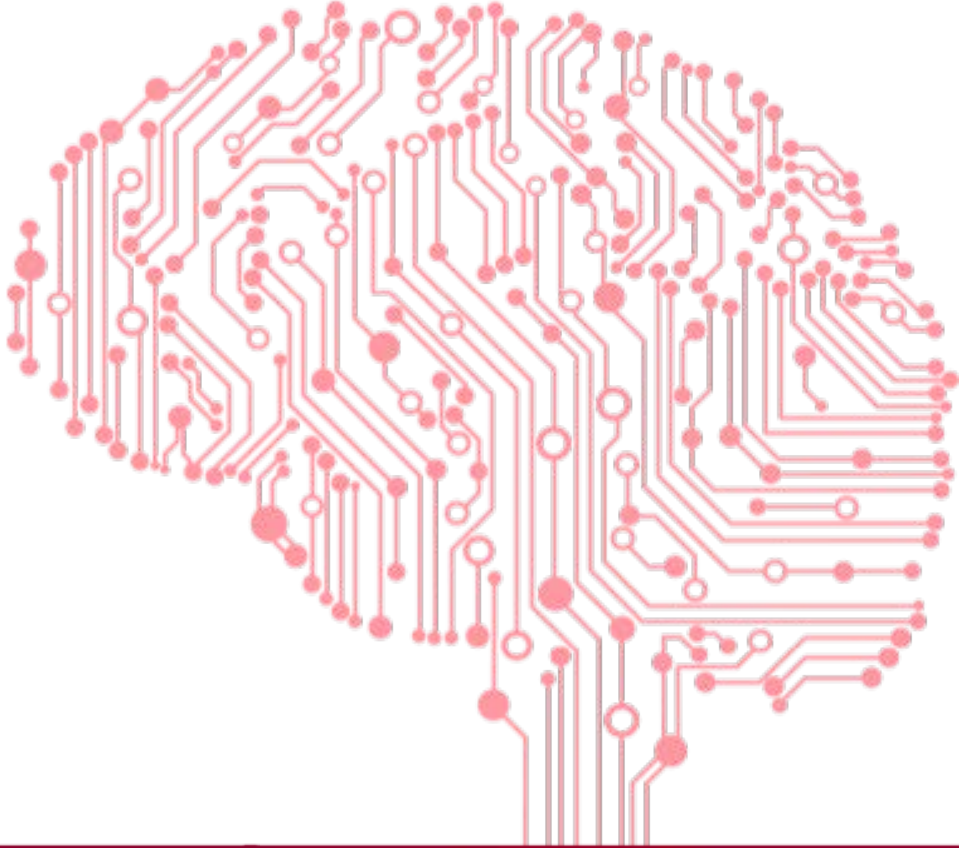
Lightning Introductions

Research Interfaces between Brain Science and Computer Science

December 3-5, 2014



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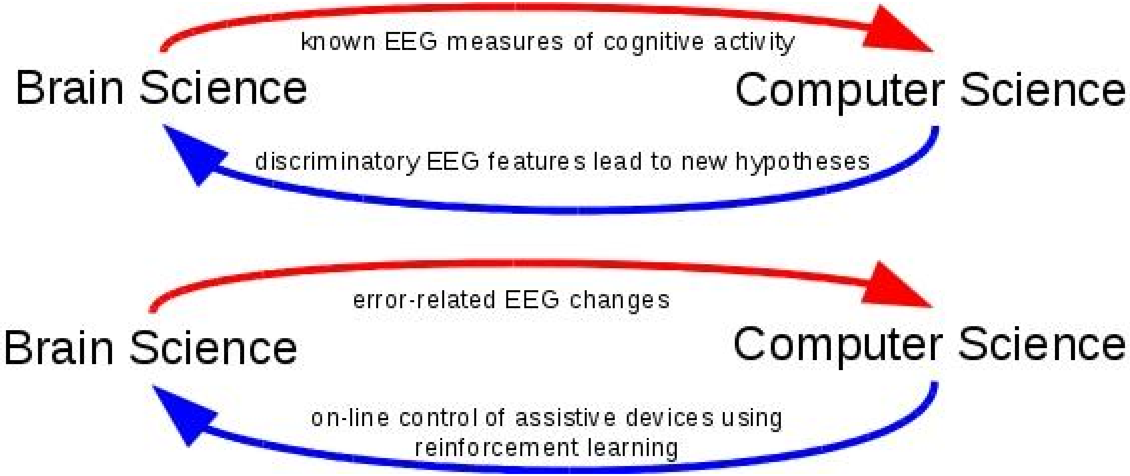
Charles Anderson / Colorado State

Brain-Computer Interfaces



Colorado State University

www.cs.colostate.edu/eeg

Sanjeev Arora / Princeton

PRINCETON UNIVERSITY

Computational complexity, designing algorithms for NP-hard problems, provably correct and efficient algorithms for ML (esp. unsupervised learning)

(Panel Moderator: Computing and the brain.)

Satinder Singh Baveja / Michigan

UNIVERSITY OF MICHIGAN

- Reinforcement Learning: Architectures for converting payoffs/rewards to closed-loop behavior in AIs and Humans
- Optimal rewards theory, or, Where do reward (functions) come from?
- Computationally Rational models for explaining animal behavior and for deriving brain mechanisms.

Andrew Bernat / CRA

CRA
Computing Research Association

How might computer science and brain science get the resources they need?

Matt Botvinick / Princeton

- Cognitive/computational neuroscience
  - fMRI, behavioral methods, neurophysiology
  - Computational modeling (deep learning, reinforcement learning, graphical models)
- Perspective: Computation as a Rosetta Stone
  - A common language in which to understand both behavior/cognition and neural function

Randal Burns / JHU

CS->Brain: Data-Intensive Web-services

- scale infrastructure to capture high-throughput imaging (1TB/day)
- integrated visualization and analytics
- semantic/spatial queries of brain structure/function

JOHNS HOPKINS
WHITING SCHOOL of ENGINEERING

idies

BRAIN->CS: Inspiration for new data organization and indexing techniques

OPEN CONNECTOME PROJECT
COLLECTIVELY REVERSE-ENGINEERING THE BRAIN ONE SYNAPSE AT A TIME.

Miyoung Chun / Kavli Foundation

The benefits are *mutual*:

- Understanding the brain will have tremendous impacts on
  - hardware (e.g. neuromorphic computing) and
  - software (e.g. image recognition, machine learning, algorithms).
- Computer Science developments are crucial to
  - analyze the data and discover the brain's circuits, and
  - aggregate, share, and collectively analyze diverse and heterogeneous neuroscience datasets.

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Christos Davatzikos / UPenn

UPENN
Center for Biomedical Image Computing and Analytics

--Brain Image Analysis

--Machine Learning and Imaging Pattern Analysis

Susan Davidson / UPenn

CS→ Brain: Novel information/analysis challenges

- "Mesoscale data" but lots of it: do databases help?
- Integrating many different types of data (e.g. image, genomic, hospital/patient)
- Privacy and security issues
- Reproducibility, data provenance, data publishing

Brain→ CS: Implications for computation/information organization and retrieval?

Ann Drobnis / CCC

Continued open engagement across the disciplines

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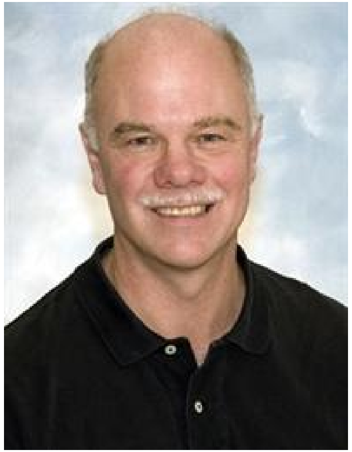

Jim Duncan / Yale

<u>Biomedical Image Analysis</u>

- model-based strategies
- Bayesian/machine learning approaches
- application areas of interest include neuro-, cardiovascular and biological (microscopy) problems

Naomi Feldman / Maryland

UNIVERSITY OF MARYLAND
Linguistics and UMIACS

Cognitive models of language acquisition and processing

- Constructing cognitive models that draw on corpora and analysis techniques from automatic speech recognition
- Using models of early language acquisition to inform zero- and low-resource speech technologies

Vitaly Feldman / IBM Research

IBM Research

Foundations of machine learning:

models, algorithmic and statistical complexity, robustness

Learning processes in nature:

Concept representation and learning in the brain

Learning via evolution

Charless Fowlkes / UC Irvine

Applying computer vision and machine learning techniques to build robust, reusable tools for biological image and shape analysis

Understanding computational role of feedback, mid-level representation and ecological statistics in visual processing

UCIrvine
University of California, Irvine

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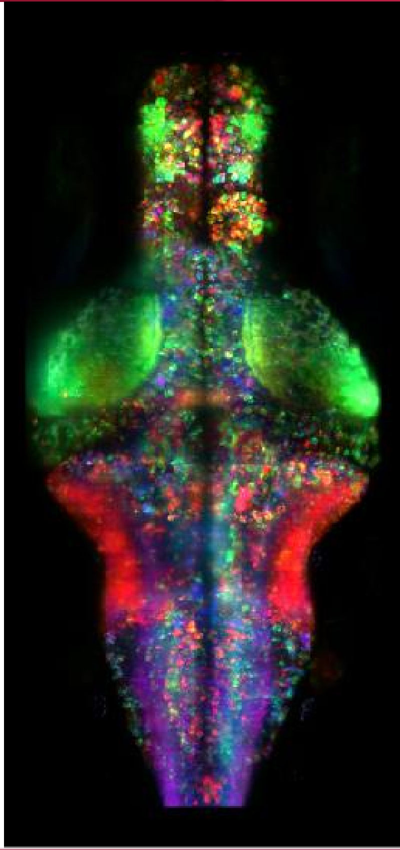
Jeremy Freeman / HHMI

Using large-scale data analytics, interactive visualization, and experimental design to map brain activity in mice, fish, and flies.

hhmi | janelia
Research Campus

*Developing open source technologies for a **modern**, **scalable**, and **collaborative** neuroscience.*



Shafi Goldwasser / MIT

Complexity Theory,
Cryptography,
Property Testing, Fault Tolerance
in Distributed Computing,
Randomness

Polina Golland / MIT

Biomedical Image Analysis

- Anatomical and functional variability from non-invasive imaging
- Functional organization of the brain
- Models of pathology
- Joint modeling of imaging and genetics

Massachusetts Institute of Technology
CSAIL

Greg Hager / JHU

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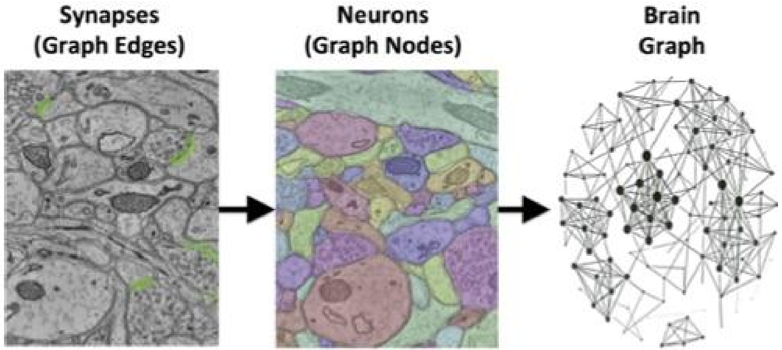
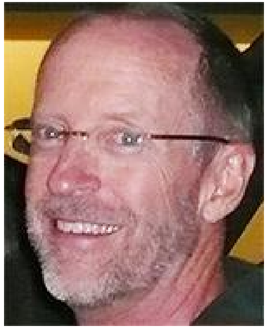
Are there universal "motifs" to brain structure and function? Do they lead us toward new models for computational perception and cognition?



Jim Haxby / Dartmouth / CIMeC(Trento)



CCN Center for Cognitive Neuroscience at Dartmouth

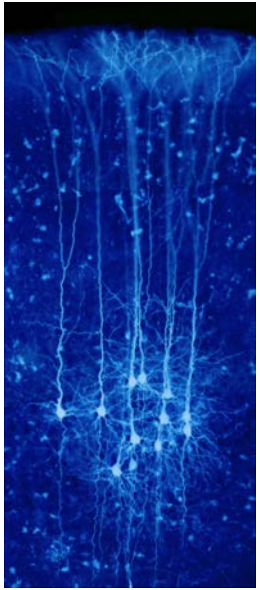
C:MeC

- MVPA – decoding neural representations from fMRI
- Hyperalignment – building a common model of representational spaces in human cortex
- HyperCortex – a functional brain atlas based on a high-dimensional common model of neural representational spaces

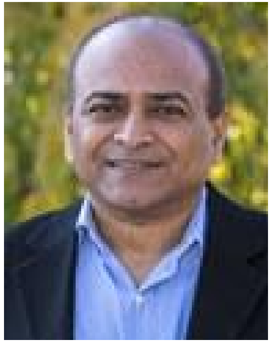
Sean Hill / Human Brain Project

Human Brain Project

An open collaborative platform for large-scale data-intensive brain research bridging brain structure and function from genes to cognition - using semantic/spatial search, multimodal data integration, provenance tracking, analysis, machine learning, visualization, modeling and simulation.



Vasant Honavar / Penn State University



PENNSTATE

- What principles govern (in both brains and machines):
  - Learning from experience
  - Learning from multimodal, multi-scale data?
  - Eliciting causal from disparate observations and experiments?
- How can we infer brain network structure and predict behavior from brain activity?

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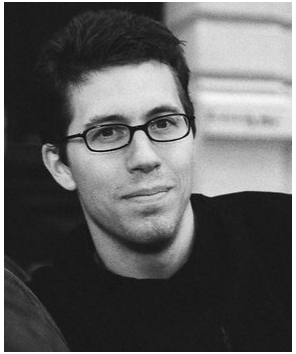
Konrad Koerding / Northwestern



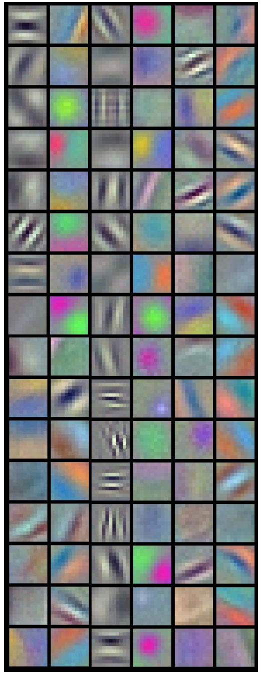
How might computer science and brain science benefit from one another?

Yann LeCun / NYU & Facebook AI Research

facebook

NEW YORK UNIVERSITY

- What are the underlying principles of learning, natural and artificial?
- How does the brain perform unsupervised learning?
- What is the neural basis of reasoning and planning?
- What are the essential architectural components?



Richard Lewis / Michigan

UNIVERSITY OF MICHIGAN

- **Computational cognitive science:** Coordinated *modeling* + *human experiments*
- **Computational rationality/bounded optimal control approaches** to *language*, *eye-movements, memory, choice..*
- **Reinforcement learning:** optimal rewards

Chris Martin / Kavli Foundation

- The question is not how the two fields will benefit each other, but how to incentivize and build upon the substantial overlap that already exists!
- By embracing and adopting the ideas coming from both sides, this room already embodies that hybrid approach.
- 100 years from now will there be (or should there be) a distinction between Computer Science and Neuroscience? When your futuristic handheld neuromorphic device gets depressed who will you take it to?

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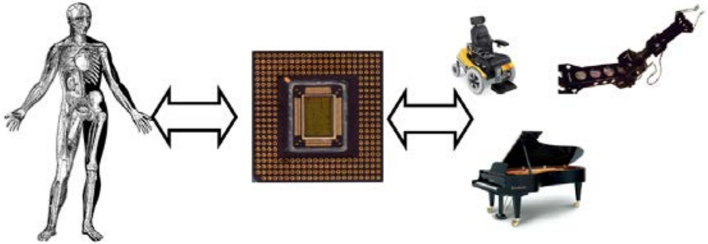
Sandro Mussa-Ivaldi / Northwestern

- How are representations of the world geometry and dynamics formed and updated through processes of sensory motor learning?
- Computational primitives and dimensionality reduction in sensory-motor control
- Human/Computer interfaces
- Synergistic interaction between human and machine learning
- Human/machine interactions for the recovery of motor functions following injuries to the nervous system



Robotics AT THE REHABILITATION INSTITUTE OF CHICAGO

Feinberg School of Medicine

Sheila Nirenberg / Cornell

- Understanding the codes neurons use and the transformations they perform

- Using this understanding to build neuroprosthetics, brain/machine interfaces, and robots

Aude Oliva / MIT

To further develop and fully engage with artificial systems at human-cognitive levels, we must understand cognition itself, and how it is mediated by the brain.

Bruno Olshausen / UC Berkeley

- Theories of sensory coding
- Natural scene statistics
- Sparse representation
- Hierarchical representation and inference in cortical circuits

Christos Papadimitriou / UC Berkeley

Simons Institute for the Theory of Computing

Algorithms and Complexity.

Game Theory and Economics.

Evolution.

How can algorithmic thinking help make progress in the sciences

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Pietro Perona / Cal Tech

- Computer Vision
- Machine Learning
- Visual perception
- Neural computation
- Behavior

Hanspeter Pfister / Harvard

HARVARD
School of Engineering
and Applied Sciences

- Visualization / Graphics / Vision
- Connectomics

Reconstructing brain circuits at the nanoscale using CS methods will allow deduction of interesting general organizational principles that in the long term will benefit CS.

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Tal Rabin / IBM Research

IBM Research

- Cryptography Research
  - Multiparty Computations
  - Threshold and Proactive Security

Rajesh Rao / U. Washington

Computer Science
Models, Algorithms, Devices

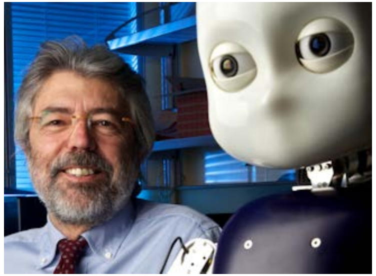
Predictive coding
Bayesian inference and learning
Acting under uncertainty
Brain-Computer Interfaces

Efficient approximate algorithms
for AI, ML, and Robotics
Novel Computer Interfaces

Brain Science
Neural Mechanisms

Understanding
Perception,
Action,
Rewards,
Behavior,
….

Giulio Sandini / Italian Institute of Technology



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iit RBCS

Robotics, Brain and Cognitive Sciences

Interests: the development of sensorimotor coordination and social interaction by studying humans and building artificial systems:

- Developmental Robotics
- Motor Cognition (Interaction, Prediction and Communication)
- Multimodal Sensory Integration.
- Motor Rehabilitation and Social Inclusion

CS-BS Mutual benefits: by sharing questions and space and discussing the “big picture” (how to assemble the brain puzzle from a topological and functional perspective)

Stefan Schaal / MPG / USC

Research interests include topics of statistical and machine learning, neural networks, computational neuroscience, functional brain imaging, nonlinear dynamics, nonlinear control theory, and biomimetic robotics. Applications to problems of artificial and biological motor control and motor learning, focusing on both theoretical investigations and experiments with human subjects and anthropomorphic robot equipment

Nicolas Schweighofer
USC

Computational Neurorehabilitation:

Brain -> CS: Models of motor learning and recovery of the lesioned brain

CS -> Brain: With predictive models, optimize re-training of the lesioned brain

Fei Sha / USC

Machine learning, with recent focus on

- How to derive useful representations from data automatically?
- How to robustly cope with changing environments w/o human intervention?

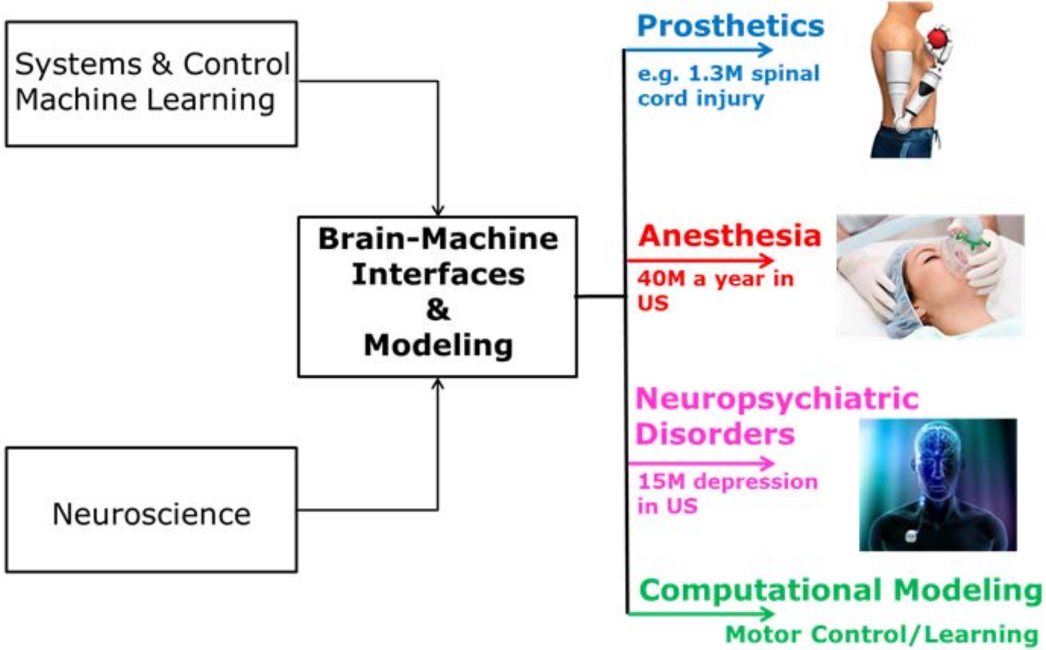
Perspective

The comparative study between artificial and biological learning systems will advance both fields significantly.

USC University of Southern California

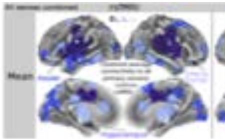
Maryam Shanechi / USC

USC Viterbi
School of Engineering
Electrical Engineering
Department



Hava Siegelman / UMass- Amherst

- 20 year fMRI DB to brain motif: heirarchical abstraction

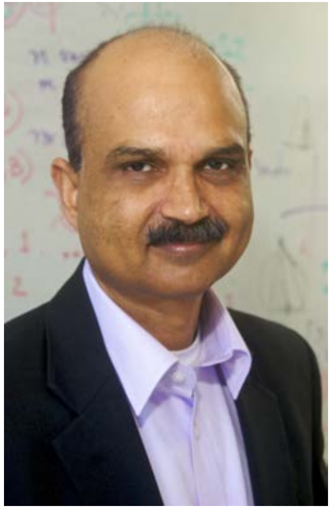


- Computing beyond the Turing limit via plastic RNN's

- Mini-circuitry: network theory u/ constraints
- Modeling memory Reconsolidation + applications in HCI HRI
- Memory-aid Technology: multi-tasking control

BINDS
BIOLOGICALLY INSPIRED NEURAL AND DYNAMICAL SYSTEMS
LAB

Ambuj Singh / UC Santa Barbara



- Network-based analysis of fMRI and DTI/DSI
- Discovery of significant fragments for learning/disease
- Noise/robustness
- Spatial network processes
- Integration of heterogeneous datasets (genetic, DTI/DSI, fMRI..)
- Population-based adaptation & diversity

James Smith

- High performance computer architecture and organization
- Spiking Neural Networks

    Temporal communication and computation

    Biological plausibility, including training

    Application to machine learning

Sara Solla / Northwestern

Background: theoretical physicist, machine learning research at Bell Labs, theoretical neuroscience research at Northwestern.

Research interests: neural control of movement, encoding of sensory input, Bayesian decision making, dimensionality reduction, dynamics of large and noisy systems, learning and adaptation.

- The neural code and its use in the complex computations performed by the brain can inspire novel paradigms of biomimetic computation.
- Machine learning tools excel at feature extraction and classification. Does the brain implement similarly generic as opposed to task specific statistical strategies?

Sharif Taha / Kavli Foundation

Computer science and brain science *will* benefit from one another, but only by actively listening the needs of both communities.

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Bertrand Thirion / Neurospin

- fMRI
- Machine learning,
- Open-source software,
- encoding and decoding,
- functional connectivity,
- Individual Brain Charting

INVENTEURS DU MONDE NUMÉRIQUE

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Francisco Valero-Cuevas / USC

USC Viterbi
School of Engineering

What physics-based problems does the brain really face and solve when controlling the body?

How do we produce versatile function with physiological sensors and actuators that are noisy, delayed and nonlinear?

These are critical questions we need to solve so that, when we interface with the nervous system, we can have a principled and effective approach to BMI and neurorehabilitation.

I address these questions by combining mechanics and neuroscience.

Les Valiant / Harvard

Computational models and theories of cortex, and their validation.

Computational Complexity

Machine Learning

Evolution

Helen Vasaly / CCC

Bringing two separate communities together

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Santosh Vempala / Georgia Tech

High-dimensional Algorithms,
Randomness, Optimization,
Foundations of ML

Georgia Tech Algorithms & Randomness Center

What is a (mathematically) plausible explanation of the cortex's ability to learn?

Not an answer by far, but here is something...

Ragini Verma / UPenn

Structural and Functional Connectomics

&

All things Diffusion Imaging

Joshua Vogelstein / JHU

- Data Intensive Brain Sciences
- Big Graph Statistics
- Wide Data Computational Statistics
- Democratizing Brain Data & Methods

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Ross Whitaker / Utah

THE UNIVERSITY OF UTAH®

- Medical image analysis
- Scientific computing
- Analysis/visualization high dimensional data and uncertainty

Rebecca Willett / Wisconsin

Machine learning provides fundamental insight into how **salient information is represented and used** to make predictions and decisions.

Brain science provides a working model of how **small, local decisions** can be lead to **complex but robust behaviors**.

Understanding each of these can significantly further the state-of-the-art in the other.