Physics of Computation
Physics 2^8B
Syllabus (Spring)

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Contents

1 Natural Computation

Theme: Causal Architecture of Dynamical Systems and Stochastic Processes

1. Prediction and Learning
2. ϵ-Machines and Causal Architecture
3. Measures of Structural Complexity
4. How to Calculate
5. Complex Materials
6. Intrinsic Semantics in Information

1.1 Lecture 21: Overview

Readings (available via course website):

- *CMR* article *Chance and Order*, Stanislaw Lem, New Yorker **59** (1984) 88–98.
- *CMR* article *Revealing Order in the Chaos*, Mark Buchanan, New Scientist, 26 February 2005; available at `csc.ucdavis.edu/~chaos/news/`.

Topics:

1. Recall Physics 2^8A
2. Introduction and motivations
3. Inadequacy of Information Theory
4. Structure and Learning
5. Survey interests, background, and abilities
6. Course logistics
7. CMPy Labs
8. Projects
9. Software and program development

Homework: Assign Week 10's today.

1.2 Lecture 22: The Learning Channel

Reading:

1. *CMR* article *RURO* (Intro) and Lecture Notes.

Topics:

1. The Learning Channel
2. The Prediction Game
3. Space of histories
4. Predictive equivalence relation
5. Causal states
6. ϵ-Machines

1.3 Lecture 23: ϵ-Machine Reconstruction

Reading: *CMR* article *CMPPSS* and Lecture Notes.

Topics:

1. Review last lecture
2. Causal states
3. ϵ-Machine reconstruction
4. Simple Processes: Predictable (Period-1), Fair Coin, and Biased Coin
5. Complex Processes: Period-2, Golden Mean, and Even Processes

Homework: Collect Week 10's and assign Week 11's today.

1.4 Lecture 24: ϵ-Machine Optimalities

Reading: *CMR* article *CMPPSS*.

Topics:

1. Optimal Prediction
2. Minimality
3. Uniqueness
4. Minimal Sufficient Statistic
5. Minimal Stochasticity

1.5 Lecture 25: Measures of Structural Complexity I

Reading: *CMR* article *CMPPSS*.

Topics:

1. Entropy rate
2. Statistical complexity
3. Excess entropy
4. Statistical complexity bounds excess entropy

Homework: Collect Week 11's and assign Week 12's today.

1.6 Lecture 25: Measures of Structural Complexity II

Reading: *CMR* article *CMPPSS*.

Topics:

1. Cryptographic Limit
2. Stored versus transmitted information
3. Pattern: Groups versus semi-groups, exact and statistical symmetries
4. Measurement Semantics
5. Excess Entropy Bound
6. Forward and Reverse Processes and their ϵ-Machines
7. Causal Irreversibility

1.7 Lecture 27: Information Diagrams for Processes

Reading: *CMR* articles *TBA* and *Yeung*.

Topics:

1. Information diagrams
2. Markov chain information diagrams
3. Shannon information measures

4. Process information diagrams

Homework: Collect Week 12's and assign Week 13's today.

Projects: Project topic should be selected by now.

1.8 Lectures 29 and 30: Directional Computational Mechanics

Reading: *CMR* articles *TBA*, *PRATISP*, and *IACP*.

Topics:

1. Forward and reverse processes
2. Causal irreversibility
3. The process lattice
4. Calculating reverse ϵ-machine from the forward ϵ-machine

Homework: Collect Week 13's due; assign Week 14's.

1.9 Lecture 31: Complex Materials I (Dowman Varn)

Reading: *CMR* articles *BTFM1* and *BTFM2*.

Topics:

1. One-Dimensional materials: Physics of polytypes
2. Experimental studies
3. Fault model

Homework: Collect Week 14's and assign Week 15's today.

1.10 Lecture 32: Complex Materials II (Dowman Varn)

Reading: *CMR* articles *BTFM1* and *BTFM2*.

Topics:

1. ϵ-Machine spectral reconstruction
2. Structure in disorder: Beyond the fault model
3. Zinc-Sulfide

1.11 Lecture 26: Mixed States (Chris Ellison)

Reading: *CMR* articles *SON* and *OCI*.

Topics:

1. Mixed states and their presentations
2. Synchronization-Control Decomposition
3. Changing presentations

Homework: No more homework. Work on your projects!

1.12 Lecture 28: The Reverse ϵ-Machine (Chris Ellison)

Reading: *CMR* articles *SON* and *OCI*.

Topics:

1. Reversibility
2. Reverse ϵ-machine
3. The bimachine
4. Excess entropy, revisited and exactly calculated

1.13 Lecture 30: Hierarchical ϵ-Machines

Reading: *CMR* article *CMPPSS*.

Topics:

1. Review Causal State Equivalence Relation
2. Hierarchical ϵ-Machine Reconstruction
3. Infinite Processes: Onset of Chaos

1.14 Lecture 36: Information Thermodynamics

Reading: *CMR* article *TBD*.

Topics:

1. Thermodynamics of Information Processing
2. The Szilard Demon
3. The Chaotic Szilard Map

1.15 Lecture 37: Intrinsic Semantics of Information I (Ryan James)

Reading: *Anatomy of a Bit* article.

Topics:

1. Information Diagrams, revisited
2. Anatomy of a Bit
3. Semantics

1.16 Lecture 39: Intrinsic Semantics of Information II (Ryan James)

Reading: *Many Roads to Synchrony* article.

Topics:

1. Cryptic and Markov Orders
2. Synchronization

2 Project Presentations

1. Presentations will be organized according to class size.
2. If the class is large, most likely they will be given at a mini-workshop, some evening.

2.1 Lecture 39: Project Presentations

2.2 Lecture 40: Project Presentations