In Transition

- from Part I: Basic Mechanisms.
- to Part II: Perception, Attention, Memory, Language, Higher Level Cognition
Summary of Part I: Basic Mechanisms

1. Biological realism
2. Distributed Representations
3. Inhibitory Competition
4. Bidirectional Activation Propagation
5. Error-driven Learning
6. Hebbian Learning

\[ \Delta w = \delta_j a_j + a_i a_j \]
Micro and Macro-Neurocomputomics

Micro = basic mechanisms common across brain areas.

Macro = organization, differentiation, interactions of brain areas.

*Need to consider general principles for macro organization before we can think about larger cognitive functions.*
Macro Structural Principles

- Hierarchical sequence of transformations.
- Specialized pathways.
- Intra-pathway interactions.
- Higher-level association areas.
- Large-scale distributed representation.
- Dedicated and content-specific.
Dedicated & Content-Specific

Neurons are dedicated to specific content (i.e., they are tuned to detect specific things).

Brain is not a general-purpose CPU.

Tradeoff between specificity & knowledge-dependency vs generality & flexibility.

Traditional symbolic AI fails because it lacks “common sense”

Time flies like an arrow.
Fruit flies like an apple.

Challenge: to build flexibility from neurons.
Macro Dynamic Principles

- Constraint satisfaction: including internal context.

- Attractors (amplification, bootstrapping...): active memory.

- Inhibitory competition: attention.
Other Areas

- Hippocampus (rapid learning).
- Thalamus (sensory input, attention).
- Amygdala (emotion, affective associations).
- Basal ganglia (BG) (sequences, motor control, gating of PFC?).
- Cerebellum (motor learning, cognitive role via timing?).
Tripartite Functional Organization

PC = posterior perceptual and motor cortex.

FC = prefrontal cortex.

HC = hippocampus and related structures.

Defined by set of functional tradeoffs.
Learning must be slow to capture (statistical) structure (averaging).

But you also have to be able to learn rapidly.

*Tradeoff* solved by 2 systems: cortex learns slowly, hippo rapidly.
Overlapping distributed representations are useful for capturing information about the world.

But overlap & interconnectivity cause spread, which is not useful for maintaining information over time.

*Tradeoff* solved by two systems: PC has overlapping distributed representations, FC is isolated for maintenance.

Active memory needs specialized updating & maintenance mechs.
A Cognitive Architecture
Important Distinctions

- Controlled vs Automatic Processing.

- Declarative/Procedural vs Explicit/Implicit.

Consciousness = influence (on Constraint Satisfaction):

- Centrality: more influence on other areas.

- Duration: longer = more influence.

- Intensity: higher = more influence.
Challenges

Networks are good at some things, but have problems with others..

- Nobody’s perfect: People tend to be bad at same things networks are..

- Don’t throw the baby out w/the bathwater!
The Binding Problem
The Binding Problem: Potential Solutions

- Attention: only focus on one item.
- Encode conjunctions: no need to have all possible conjunctions separately represented.
- Dynamic synchrony: things that fire together go together.
- Nobody’s perfect: people make tons of binding errors..
Other General Problems

- Representing multiple instances of the same thing (attention + counting, location)

- Comparing representations (overlap – multiple digits, settling in shared weights – goodness, PMC-PFC)

- Nobody’s perfect...
Recursion and Subroutine-like processing

- In middle of processing, need to perform same processing (recursion) or different processing (subroutine)

- Easy in standard serial computer (store current state, call subroutine w/appropriate arguments)

- Harder when data and processing not separated!

- HCMP, PFC

- Nobody’s perfect...
  The mouse the cat the dog bit chased squeaked.
Generalization

How to recognize new inputs given dedicated, specialized reps?

- Distributed representations: combinations of existing features.
- Abstraction: learn that all dogs might bite, not just that spike bit me..
- Nobody’s perfect: Transfer is not good at all..