Connectionism: Localized networks

Phil/Psych 256

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Overview

- Classic CogSci: representations & procedures, e.g.,
  - Rules and search
  - Concepts and association
  - Images and imagery
- There is some tension built into the classic paradigm

Overview (cont.)

- Another model of cognition: the human brain
  - Perhaps knowledge and cognition are best understood as results of the brain working
- Discuss localized and distributed artificial neural networks as models of cognition

	Model	Representation	Procedures	Operation
Classic CogSci	Digital computer	Symbols	Search or association	Serial
Connectionism	Brain	Units and constraints	Constraint satisfaction	Parallel

The neuron doctrine

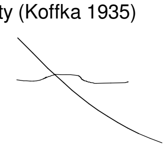
- Importance of the brain to cognition suggested by Theophrastus (372–287 BC)
- Anatomical studies undertaken in the 16th Century, e.g, daVinci (1452–1519), Vesalius (1514–1564)
- Phrenology developed in the 19th Century, e.g., Gall (1758–1828)
  - Brain regions subserve specific faculties, e.g., memory, language, guile
- The functional specialization of brain regions is part of Cognitive Neuroscience

The neuron doctrine (cont.)

- Descartes (1596–1650) concluded that the brain consists of small bodies that act in concert to produce behaviour
  - E.g., by hydraulic pressure
- Waldeyer (1891): the *neuron doctrine*
  - The brain consists of billions of discrete units (neurons)
  - Neurons are specialized cells
  - Neuronal interaction produces behaviour

Constraint satisfaction

- How does neuronal activity give rise to behaviour?
- Gestaltists claimed that cognition involves **optimization**
  - E.g., simplicity (Koffka 1935)



Constraint satisfaction (cont.)

- In the 1940s:
  1. Neurons constrain the activity of other neurons
  2. The whole network maximizes the satisfaction of these constraints
- McCulloch & Pitts (1943) showed that such networks could compute propositional functions
- Hebb (1949) *cell assembly* theory showed that such networks could learn
  - "The problem of understanding behaviour is the problem of understanding the total action of the nervous system and vice versa"

Simplified neural networks

- A network has two components:
  1. A set of nodes (e.g., neurons) and
  2. A set of connections among nodes (e.g., synapses).

Simplified networks (cont.)

- In a simplified model, focus on
  - The **activation level** a [0…1] of each node N
  - Links between nodes
- Each link
  - has a connection strength
  - Is either
    - **Excitatory** (enhances activation)
    - **Inhibitory** (suppresses activation)
  - So, has a **connection weight** w [-1…1]

Simplified networks (cont.)

- The signal N_1 passes to N_2 is
  - $a_1 \bullet w_{1,2}$
- A signal may have one of three effects
  1. If $a_1 = 0$, then $a_1 \bullet w_{1,2} = 0$, meaning that N_1 exerts no influence on N_2.
  2. If $a_1 > 0$, then $a_1 \bullet w_{1,2}$ will have the same sign as the weight $w_{1,2}$.
     a) If $w_{1,2} > 0$, then the input to N_2 is positive, that is, **excitatory**.
     b) If $w_{1,2} < 0$, then the input to N_2 is negative, that is, **inhibitory**.

Spreading activation

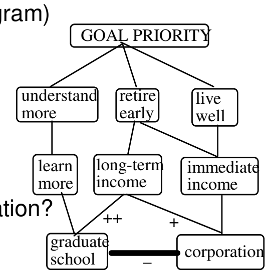
- A node receives inputs from many nodes
- The total input is the sum of the individual inputs
- To compute its new activation, each node has an **activation function**
  - The sigmoid function is often favoured

Localized networks

- Localized network: symbolic meanings are assigned to nodes
  - Each link is a constraint on the activation of nodes
  - Nodes compete for activation from inputs
- To perform a function, allow network activation to settle
  - Active nodes fit the presented input
  - Inactive nodes do not fit

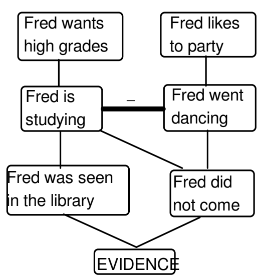
Decision making

- DECO (Thagard & Millgram)
- Nodes:
  - Actions
  - Goals
- Links [bidirectional]:
  - Facilitation (+)
  - Incompatibility (-)
- What to do after graduation?



Explanation

- ECHO (Thagard)
- Nodes:
  - Evidence
  - Hypotheses
- Links:
  - Explanation (+)
  - Analogy (+)
  - Contradiction (-)
  - Competition (-)
- Why did Fred not show up?



Evaluation: strengths

- Localized networks are transparent
  - Nodes and connections have natural meanings
- Settling procedure is effective
  - **Usually** finds best solution (80%)
  - Sometimes settles on a suboptimal response
- The approach is flexible
  - Can be applied to many kinds of cognitive tasks
- Neurologically plausible
  - Uses parallel, not serial, procedure

Evaluation: limitations

- Localized networks do not learn well
  - Exception: Copycat (Hofstadter)
  - Assume nodes and constraints are known at outset
- Some logical relationships not naturally captured
  - *and* (p & q) = symmetric excitatory link
  - *not-both* ~(p & q) = symmetric inhibitory link
  - *if-then* ($p \rightarrow q$) = asymmetric excitatory link
  - *or* ($p \vee q$) = ??
- Localized representations are not brain-like
  - E.g., no “grandmother” neuron