CHAPTER SEVEN

The Network Approach: Mind as a Web
Connectionism

- The major field of the network approach.
- Connectionists construct *Artificial Neural Networks* (ANNs), which are computer simulations of how groups of neurons might perform some task.
Information Processing

- ANNs utilize a processing strategy in which large numbers of computing units perform their calculations simultaneously. This is known as parallel distributed processing.
- In contrast, traditional computers are serial processors, performing one computation at a time.
Serial and Parallel Processing Architectures

Serial processing architecture

Parallel processing architecture
Approaches

- The traditional approach in cognition and AI to solving problems is to use an algorithm in which every processing step is planned. It relies on symbols and operators applied to symbols. This is the *knowledge-based approach*.

- Connectionists instead let the ANN perform the computation on its own without any planning. They are concerned with the behavior of the network. This is the *behavior-based approach*.
Knowledge Representation

- Information in an ANN exists as a collection of nodes and the connections between them. This is a *distributed representation*.
- Information in semantic networks, however, can be stored in a single node. This is a form of *local representation*. 
Characteristics of Artificial Neural Networks

- A *node* is a basic computing unit.
- A *link* is the connection between one node and the next.
- *Weights* specify the strength of connections.
- A node fires if it receives activation above *threshold*.
Characteristics of Artificial Neural Networks

- A *basis* function determines the amount of stimulation a node receives.
- An *activation* function maps the strength of the inputs onto the node’s output.

A sigmoidal activation function

A sigmoidal activation function
Hebb (1949) describes two types of cell groupings.

- A **cell assembly** is a small group of neurons that repeatedly stimulate themselves.
- A **phase sequence** is a set of cell assemblies that activate each other.
Early Neural Networks

- Perceptrons were simple networks that could detect and recognize visual patterns.
- Early perceptrons had only two layers, an input and an output layer.
Modern Artificial Neural Networks

- More recent ANNs contain three layers, an input, hidden, and output layer.
- Input units activate hidden units, which then activate the output units.
Backpropagation Learning in Artificial Neural Networks

- An ANN can learn to make a correct response to a particular stimulus input.
- The initial response is compared to a desired response represented by a teacher.
- The difference between the two, an error signal, is sent back to the network.
- This changes the weights so that the actual response is now closer to the desired.
Features of Artificial Neural Networks

- *Supervised networks* have a teacher. *Unsupervised networks* do not.
- Networks can be either *single-layer* or *multilayer*.
- Information in a network can flow forward only, a *feed-forward network*, or it can flow back and forth between layers, a *recurrent network*.
Network Typologies


- **Kohonen networks.** An example of a two-layer, unsupervised network. Able to create topological maps of features present in the input.

- **Adaptive Resonance Networks (ART).** An unsupervised multilayer recurrent network that classifies input patterns.
Evaluating Connectionism

- **Advantages:**
  1. Biological plausibility
  2. Graceful degradation
  3. Interference
  4. Generalization

- **Disadvantages:**
  1. No massive parallelism
  2. Convergent dynamic
  3. Stability-plasticity dilemma
  4. Catastrophic interference
Semantic Networks

- Share some features in common with ANNs.
- Individual nodes represent meaningful concepts.
- Used to explain the organization and retrieval of information from LTM.
Characteristics of Semantic Networks

- **Spreading activation.** Activity spreads outward from nodes along links and activates other nodes.
- **Retrieval cues.** Nodes associated with others can activate them indirectly.
- **Priming.** Residual activation can facilitate responding.
Hierarchical Semantic Network

- Sentence verification tasks suggest a hierarchical organization of concepts in semantic memory (Collins and Quillian, 1969).
- Meaning for concepts such as animals may be arranged into superordinate, ordinate, and subordinate categories.
- Vertical distance in the network corresponds to category membership.
- Horizontal distance corresponds to property information.
Propositional Networks

- Can represent propositional or sentence-like information. Example: “The man threw the ball.”
- Allow for more complex relationships between concepts such as agents, objects, and relations.
- Can also code for episodic knowledge of events.
Network Science

- An emerging field of study that examines networks in general. All kinds of networks.
- Hierarchical networks are found throughout the brain.
- In the visual system simple cells feed complex cells which feed hypercomplex cells
Visual System Organization

- Angle Detectors (End-Stopped Cells)
  - Oriented line or corner moving in a particular direction

- Moving Line Detectors (Complex Cortical Cells)
  - Oriented bar moving in a particular direction

- Line Detectors (Simple Cortical Cells)
  - Oriented bar of light or dark

- Dot Detectors (Retinal Ganglion and LGN cells)
  - Spot of light or dark against contrasting background

Convergence
Small-World Networks

- Four degrees of Kevin Bacon
- Only a small number of links connect any two nodes in these networks
- True for many networks including the U.S. electrical powergrid, roads and railroads and in the nervous systems of many animals
- How can this be?
Ordered and Random Connections

- **Ordered connections** are local and short distance. Many steps are required to link nodes in these networks. Steps are measured as average path length.

- **Random connections** are global and long distance. A smaller number of steps can link nodes in these networks.

- Watts and Strogatz (1998) found that only a few random connections need to be added to an ordered network in order to reduce average path length and turn them into small-world networks.
Ordered and Random Connections

A local network

A randomized network
There are two types of small-world networks.

*Egalitarian networks* are mostly ordered with a few random long-distance links thrown in. Social networks are an example.

*Aristocratic networks* are hub-based. Some nodes have many links while others have few. The world wide web is an example.

Hub nodes gain links through a process of preferential attachment.
Neuroscience and Networks

- Cat and monkey brains are small-world networks. Humans as well.
- This is necessary for survival since in emergencies messages must be transmitted quickly.
- Unfortunately, this organization also allows *epileptic seizures* to spread.
Small-World Networks and Synchrony

- *Synchrony* occurs when neurons fire at the same rate and is responsible for coordinating activity across large brain distances (as in perceptual binding).
- Researchers have found that synchrony is difficult in purely ordered or purely random networks.
- But it happens easily in small-world networks.
Percolation

- Networks are good ways to model the spread of disease.
- *Percolation* refers to the spread of a disease through a network.
- It happens quickly and infects a large portion of the network if there is a *percolating cluster*, a single giant group of susceptible nodes connected by open links.
- It happens slowly and infects a small portion of the network if there is no such cluster.
There are many examples of what may be called percolating clusters in psychology. Disorganized thinking in schizophrenics is one. Divergent thinking in creative individuals is another.
Networks can be used to represent emotional states (Bower, 1981).

Different emotions like sadness can be assigned to particular nodes. When the node is activated, that emotion is experienced.

The cognitive node representing your ex-girlfriend probably became linked to a sad node during or after the break up.

So when thinking about her, spreading activation from the cognitive node to the associated emotion node will trigger sadness.
Cognitive-Emotion Networks

- Links in these networks are two-way. Being sad can also make you think about your ex-girlfriend.
- They can also be used to explain the mood congruency effect whereby it is easier to recall items in a certain mood if that mood was also present during the initial study period.
- Inhibitory connections are also possible. Opposite emotions like happiness and sadness are probably linked this way. Being happy is less likely to make you feel sad.