**ABSTRACT**

An artificial neural network was trained to rate the distances between pairs of cities on the map of Alberta, given only place names as input. The issue of interest was the nature of the representations developed by the network's hidden units after it successfully learned to make the desired responses. A number of different analyses indicated that the network's hidden units had developed metric representations of space. The manner in which this network completed this task has implications for the representation of spatial relationships in biological systems, specifically, how place cells in the hippocampus may represent spatial information.

**METHODS**

From a map of Alberta, we determined the shortest distance in kilometres between each pair of locations. These distances were then converted into ratings.

**RESULTS**

The hidden units of the network did indeed develop metric representations of space as indicated by the following analyses:

- 2 dimensional multi-dimensional scaling analyses accounted for almost all of the variance in the activation matrix for each hidden unit.
- Assuming each hidden unit occupies its own position on the map, the position for each hidden unit produces a high correlation between the distances, the origin of the MDS plot and the Gaussian-transformed distances between cities and the location of the hidden unit.

**CONCLUSIONS**

Although this artificial neural network was not explicitly given metric input, after training, it produced metric responses. Our analyses indicate that the connection weights to the hidden units are responsible for this metric behavior. Due to coarse coding, each hidden unit itself does not produce activity that reflects the configuration of the map of Alberta but the activation of the entire network produces an accurate simulation of the place positions. This demonstrates that a system with only six processing units can represent the spatial relationships between thirteen different landmarks. The implication for biological systems is that they need not be organized topographically. Instead, locations of landmarks in the environment could be represented as a pattern of activity distributed over a number of different place cells.

**NETWORK ARCHITECTURE**

The network was a network of value units that had 10 output units, 6 hidden units, and 13 input units. Each input represented one of the 13 place names. Pairs of place names were presented as stimuli by turning two of the input units on (activated at a value of 1). All of the other input units were turned off (activated by a value of 0). The input units themselves did not provide any metric information to the network.

- For each hidden unit, one could find a vector that passed through the MDS plot such that when city locations are projected onto this vector, there were very high correlations between these projections and the connection weights feeding into the hidden unit.
- Assuming each hidden unit occupies its own position on the map, one could find a location for each hidden unit that produced a high correlation between the connection weights feeding into the hidden unit and the distances on the map between cities and the position of the hidden unit.

**How might an artificial neural network represent metric space?**

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