INFO 7375 - Neural Networks & AI

Quiz - 8

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What are the major principles of Recurrent Neural Networks and why are they needed?

Recurrent Neural Networks (RNNs) are a class of neural networks designed specifically to process sequential data by maintaining an internal state or "memory" that captures information from previous time steps. Unlike feedforward networks that process each input independently, RNNs contain loops that allow information to persist across sequence elements. The fundamental innovation is the introduction of recurrent connections where the network's hidden state at time t depends not only on the current input x_t but also on the previous hidden state h_{t-1}, formally expressed as $h_t = f(W_h h * h_{t-1} + W_x h * x_t + b_h)$, where W_{hh} represents the recurrent weight matrix, $W_{xh}$the input weight matrix, and b_h the bias term.

The necessity for RNNs arises from the inherent limitations of traditional feedforward networks when dealing with sequential data. Standard neural networks assume fixed-size inputs and outputs with no temporal dependencies between data points, making them unsuitable for tasks where context from previous inputs influences current predictions. Natural language processing exemplifies this need perfectly understanding a word's meaning often requires knowing the words that came before it. Similarly, time series prediction, speech recognition, video analysis, and music generation all involve patterns that unfold over time where the order and temporal relationships between elements are crucial. RNNs address this by sharing parameters across time steps and maintaining a hidden state that theoretically can capture arbitrary long-range dependencies, though in practice they face challenges with very long sequences.