Modern Hopfield Networks

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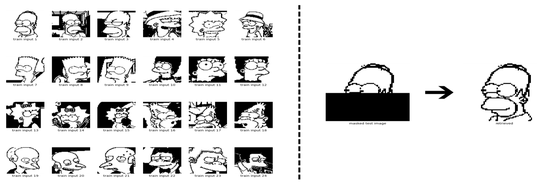
Introduction

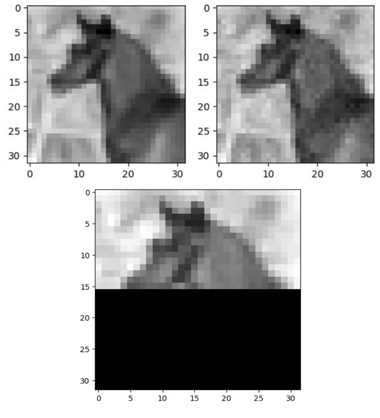
Hopfield Networks are associative memory networks whose purpose is to connect the input with its most similar pattern. This is performed by calculating an energy function but is limited to binary inputs (black and white images). Modern Hopfield networks update such function so its able to work on grayscale images.



Preprocessing

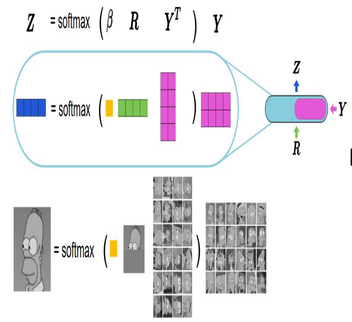
We used images from the CIAR10 Dataset. We provide the option to let users decide how many images to use. The images will be chosen at random.

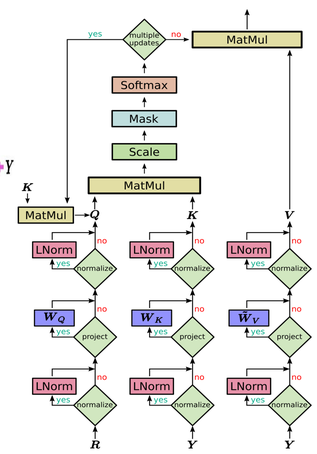
We maintain two different sets of images: one RGB and one grey. We apply gaussian blur to the images and optionally apply a mask to others.



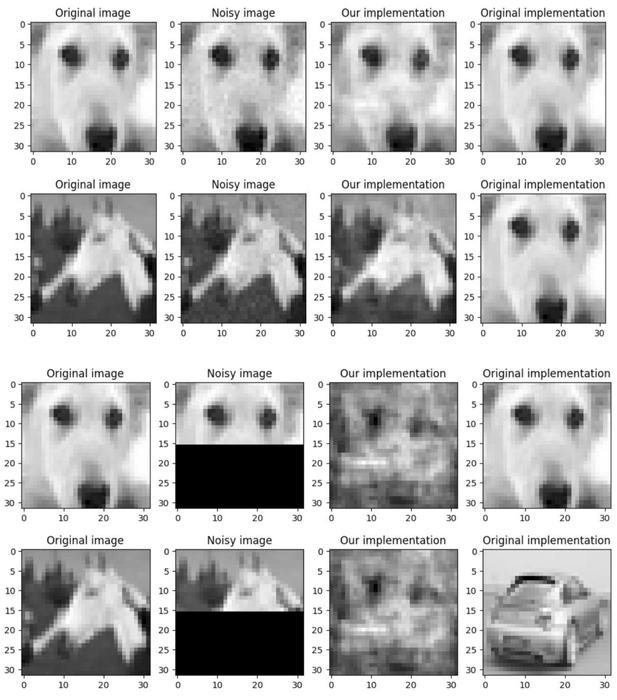
Architecture

- **Core Idea**: It's a modern version of the classic Hopfield network, but with *continuous-valued states* (not binary) and a new update rule.
- **Key Features**:
  - **Exponential Storage**: Can store and retrieve *exponentially many patterns* (relative to the dimension of the data space)
  - **Three Types of Memory**:
    - *Global averaging*: Combines all stored patterns.
    - *Metastable states*: Averages subsets of patterns.
    - *Single patterns*: Stores and retrieves individual patterns.
- **Link to Transformers**: The update rule is mathematically *equivalent to the attention mechanism* in transformers. Early layers tend to globally average, while deeper layers focus on subsets (metastable states).
- **Practical Use**: Can be added to deep learning models as *"Hopfield layers"* to act as memory, attention, or pooling mechanisms. They're more flexible than standard layers (e.g., CNN, RNN).
- **Difference**: We implement a different similarity equation than expressed in the paper based on measuring the distance.

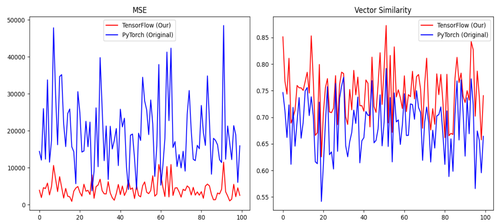




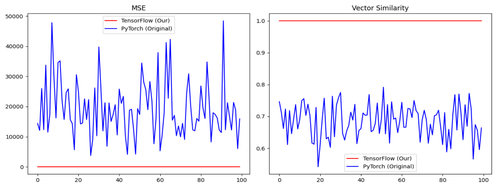
Results



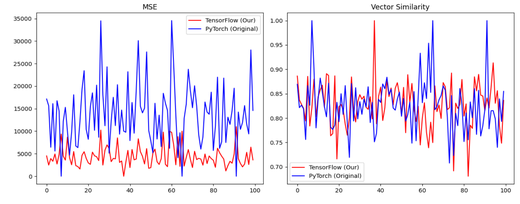
100 RGB images, scaling=1e5, noise std=5



100 RGB images, scaling=1e6, noise std=5



100 gray images, scaling=1e5, half mask



Discussion

- Our model is better on this task
- Scale change greatly influences performance
- Future development:
  - Look for ways to increase memory
  - Test on more images
  - Train learnable features