Deep Cyclic Group Networks

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[Project Website] **https://github.com/zcfan-tw/vectorNNtoolbox**

Motivation

An increasing number of multi-dimensional data
- Multispectral image denoising
- Multispectral image segmentation
- EEG-based emotion recognition

Vector-valued networks are proposed to learn mutual associations among different dimensions (Dimensionality *N*) in multi-dimensional data
- Deep complex neural network [1-2] (*N*=2)
- Vector-product neural network [3] (*N*=3)
- Deep quaternion neural network [4-5] (*N*=4)

From Previous works
- Scalar-valued neurons become vector-valued neurons
- Inputs, outputs, weights and biases are vector values

Drawbacks of previous works
- The dimensionality *N* in these models is fixed, such that they can not process arbitrary-*N* dimensional data

Deep cyclic group network (DCGN)
- Dimensionality *N* is an arbitrary positive integer
- Vector-valued neurons with cyclic group algebras
  - Circular convolution
- Kernel maps and feature maps are three-way tensors
- Derivation of backpropagation learning algorithm, weight initialization, and batch normalization

Proposed Model

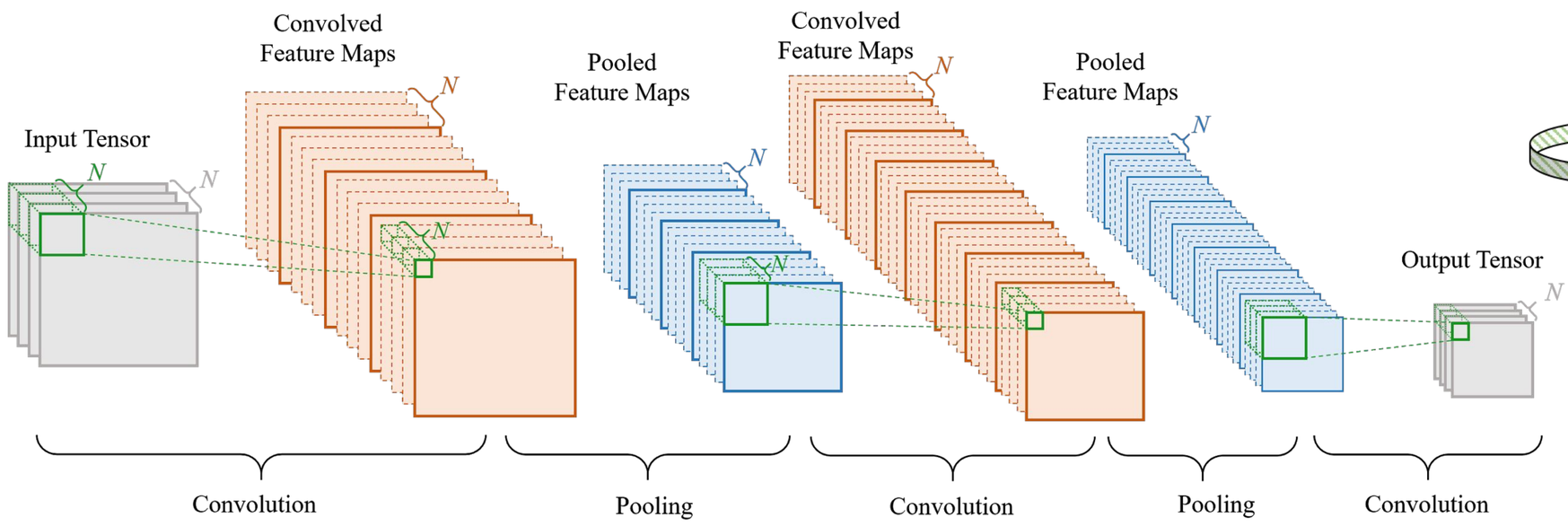


Illustration of the proposed DCGN model for regression problems
- Orange squares, blue squares and green squares are convolved features, pooled features and kernel maps respectively
- The feature and kernel maps are three-way tensors
  - When *N* is 1, the model reduces to conventional CNN
- All feature maps across all the layers have the same dimensionality *N*
- The kernel map can learn the association between the elements across the *N* dimensions

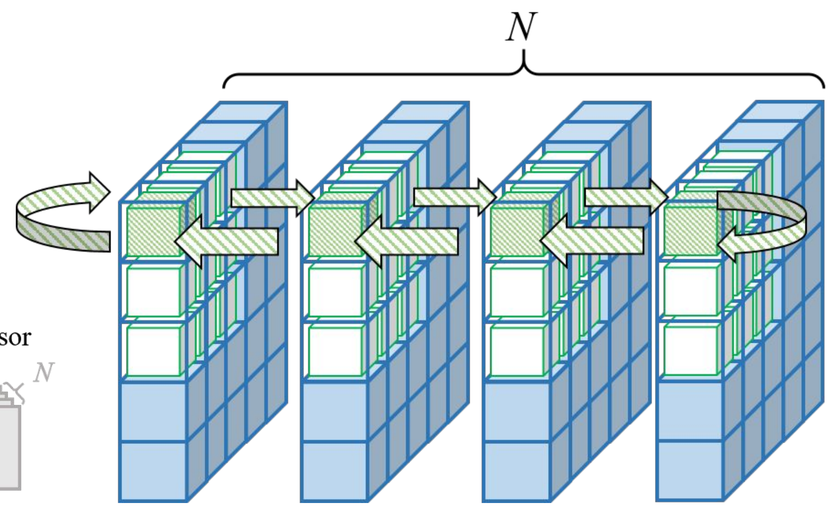
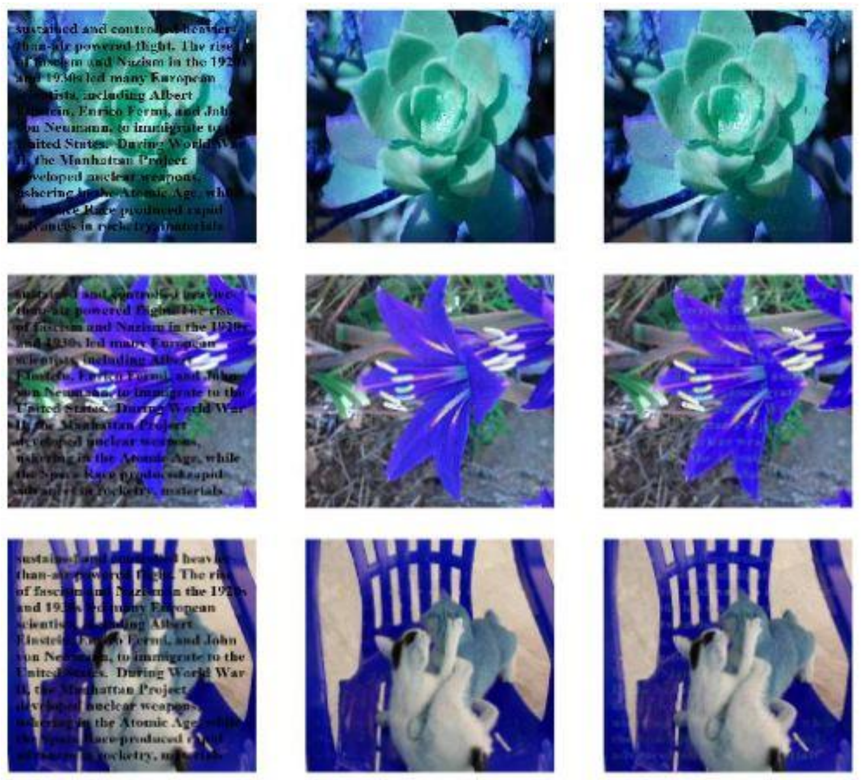


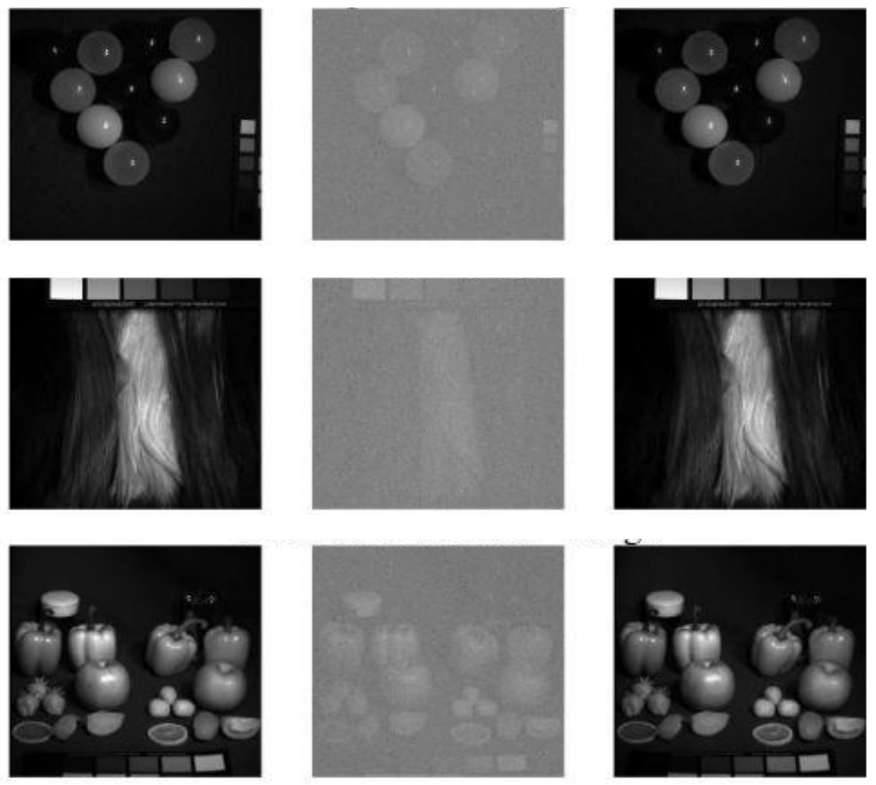
Illustration of the convolution procedure with circular convolution
- Each cube represents a scalar.
- Each matrix is a frontal slice of the tensor
- Each mode-3 fiber is an *N*-dimensional vector
- The feature map and the kernel map are composed of blue cubes and green cubes respectively
- Each mode-3 fiber of the kernel map performs circular convolution with a mode-3 fiber of the feature map, by rotating itself along the mode-3 dimension

Experiments

Color Image Denoising (*N*=3)
- Contaminate images by texts with variant fonts
- Comparison between DCGN and CNN under similar number of parameters



Multispectral Image Denoising (*N*=5)
- Add Gaussian noise with the specific sparsity and sigma value
- Sparisty: 10% Sigma: 200



Future Work

- Test DCGN on classification problems and datasets with even larger dimensions

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