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Processing of incomplete images by (graph) convolutional neural networks

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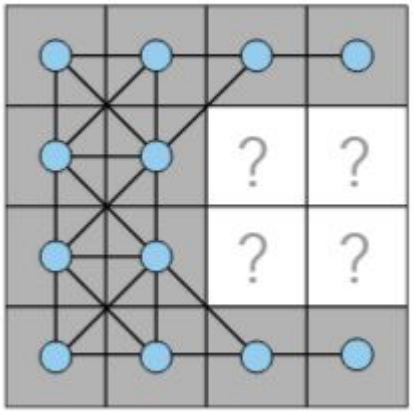

We investigate the problem of **processing incomplete images** by neural networks **without replacing missing values**.

- We first represent an image as a graph, in which missing pixels are entirely ignored.
- The graph image representation is processed using a Spatial Graph Convolutional Network (SGCN) — a type of graph convolutional neural networks, which is a proper generalization of classical CNNs operating on images.

Spatial Graph Convolutional Network

In SGCN node aggregation is given by the formula:

$$\bar{\mathbf{h}}_i(\boldsymbol{U}, \mathbf{b}) = \sum_{(v_i, v_j) \in E} \mathrm{ReLU}\left(\boldsymbol{U}\left[\begin{pmatrix} j_x \\ j_y \end{pmatrix} - \begin{pmatrix} i_x \\ i_y \end{pmatrix}\right] + \mathbf{b}\right) \odot \mathbf{h}_j,$$

where the intensities $\mathbf{h}_j$ of adjacent pixels v_j are multiplied by a non-linear transformation of relative pixel positions. $\boldsymbol{U}$ and $\mathbf{b}$ are trainable parameters of the aggregation step. Afterwards, an MLP is applied to the aggregated node outputs.

Incomplete image classification

We compare SGCN with GCN without pixel positions and CNNs with missing values imputed by zeros (with mask), the mean value or *k*-Nearest Neighbors.
The table shows the **classification error** for two datasets with **randomly removed patches**: MNIST with removed 13x13 patches and SVHN with removed 15x15 patches.

Dataset	SGCN	GCN	CNN (mask)	CNN (mean)	CNN (k-NN)
MNIST	**4.6%**	31.4%	4.9%	5.9%	5.7%
SVHN	**16.6%**	74.6%	18.6%	19.9%	22.4%

Image reconstruction

We consider images taken from the MNIST dataset and use the same size of removed patches as before. Analogical autoencoder models with different types of convolutional encoder layers are used to reconstruct the missing region. We also show the results of mean value imputation and k-NN algorithm.

We assume that the complete data are not available in training phase (MSE is calculated outside the missing region).

Our method is comparable to the CNN models but **can be trained end-to-end** since it does not depend on the imputation methods.