

## Bivariate Neural Network operators based on B-spline functions

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I introduce and study a class of neural network operators whose activation mechanism is built from cardinal B-splines. The compact support and smoothness of B-splines lead to localized approximation processes that fit naturally into the theory of positive operators. I prove convergence results and investigate qualitative features such as shape preservation, showing that several geometric properties of the target function are inherited by the approximants. A central part of the analysis is the derivation of Voronovskaja-type asymptotic formulas, which provide a refined description of the local rate of convergence and highlight the role of the underlying spline moments. The construction is further extended to a bivariate tensor-product setting, where analogous convergence and asymptotic results are obtained together with axial shape preserving properties. Finally, I illustrate the method by numerical experiments in image processing, and I report standard similarity measures (SSIM and PSNR) to assess the quality of the reconstructed images.

Keywords: Neural network operators; positive linear operators; B-splines; shape preserving approximation; Voronovskaja-type formula; image processing.

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