Advancing Stability in Deep Learning: Exploring the Superiority of Sqr-ResNet in Function Interpolation, Computer Graphics, and PDE Problem-Solving

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Abstract

This talk introduces an innovative strategy to enhance the stability of adaptive feedforward architectures in deep learning, specifically focusing on function interpolation, computer graphics, and partial differential equations (PDEs). The proposed approach leverages a distinctive Residual Network (ResNet) variant, the squared residual network (SqrResNet). While ResNet is commonly associated with convolutional neural networks, SqrResNet stands out as an excellent algorithm for integration into feedforward networks, substantially improving computational stability. The investigation thoroughly explores back-propagated gradients to loss values, underscoring SqrResNet's exceptional ability to balance different loss terms during model training. This represents a clear improvement over plain neural networks and ResNet. In the domain of function interpolation, we evaluate both smooth and non-smooth functions in both 2D and 3D settings. Furthermore, SqrResNet is tested in computer graphics scenarios involving intricate models such as the Stanford Bunny and in medical imaging applications. The method extends to solving forward and inverse PDE problems, with a detailed comparison to the DeepXDE package using a plain neural network in its feedforward algorithm. The following observations have been made across various examples in these diverse fields:

- SqrResNet consistently outperforms both ResNet and plain neural networks, demonstrating superior accuracy, stability, and convergence.
- SqrResNet stands out for its impressive performance, especially when plain neural networks struggle to train or face divergence shortly after some epochs.
- SqrResNet exhibits exceptional stability, even with over 50 hidden layers, aiming for enhanced accuracy.
- The study underscores the problem-dependent nature of the number of hidden layers, revealing that deeper networks (exceeding 10 hidden layers) often yield better accuracy. In contrast, plain neural networks opt for fewer hidden layers to address instability with larger layer counts.

These findings underscore the substantial advantages of SqrResNet over conventional ResNet and plain neural network architectures.

Keywords: SqrResNet, ResNet, neural network, stability, function interpolation, computer graphics, medical imaging, PDEs, deep learning, extensive hidden layers.