Artificial Neural Network (ANN) with Unique Input Design that Significantly Reduces Computational Costs of Complex Engineering Systems

System circumvents challenges in using neural networks for solving differential equations with multiple discontinuities in solutions

Large-scale ANN computations that require numerous repetitive calculations can be costly and may produce incomplete results. Existing technologies are unable to accurately predict solutions involving rapid state changes (e.g., shockwaves, contact discontinuities, thermodynamic phase changes, material disparities). The common input deficiencies limit the ANN from capturing such discontinuities. For example, in comparisons of assessments of a shock wave and a smooth wave in the same space-time domain, current low-resolution solutions would not offer differentiated output.

Superior local converging-solution input can decrease costs while increasing accuracy

This novel method offers a unique input design that provides a low-cost solution to achieve highly accurate results. The ANN has an innovative input system that processes low-cost numerical solution patches arising from a sequence of solutions that converge toward the exact solution of the differential equations. When a considerable number of repetitive calculations are required, the savings of using this technology can be realized quickly. The input's unique design is efficient as it utilizes local space-time patches covering the local domain of dependence, unlike the existing standard ANN. The complete input strategy enables the ANN to accurately predict large-scale solutions of differential equations with multiple discontinuities. A shock wave and smooth wave will have differentiated output with sharper resolution than present industry standards. Industrial design processes (e.g., engine chamber design, aircraft shape optimization, structure design) as well as scientific research benefit from the adaptability of this technology as a stand-alone solution or in combination with pre-existing commercial software.

Summary Bullets

- Neural network's novel input can utilize first-order schemes and local patches and allows for discontinuities to be reflected accurately and with greater resolution than existing products.

- This adaptable ANN can be adopted by commercial and scientific research as a stand-alone solution or in conjunction with existing software.
- Lower costs for running complex and repetitive computations can be achieved by implementing this neural network with an input system that processes low-cost numerical solution patches arising from two or more converging solutions.

Solution Advantages

- **Accurate**: Novel multi-solution input enables an ANN to accurately predict solutions, even if multiple discontinuities exist.
- **Lower cost**: When an ANN has a significant number of calculations that are repetitive, employing this technology's low-cost numerical solutions for input will result in immediate cost savings.
- **Adaptable**: This technology can stand-alone or be implemented in combination with pre-existing industrial design software.

Potential Commercial Applications

- Automobile aerodynamics
- Aircraft shape optimization
- Gas dynamics modeling
- Antenna design
- Engine design
- Battery optimization
- Building and structure design
- Industrial design and optimization
- Real time computation for financial derivatives

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IP Status

<p>Patent application has been filedn</p>: US63/341123

Publications

[Neural Networks with Inputs Based on Domain of Dependence and A Converging Sequence for Solving Conservation Laws, Part I: 1D Riemann Problems](), Computer Science, ArXiv - September 20, 2021

Images

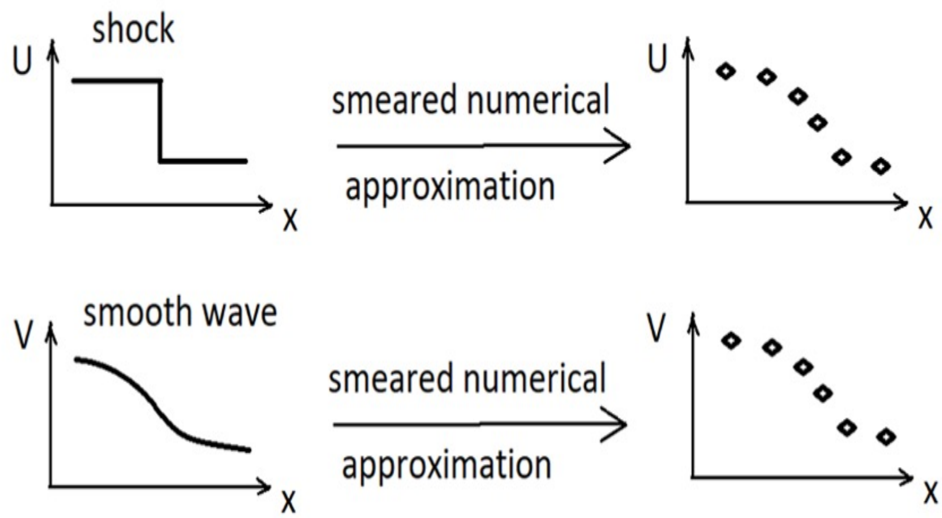

Figure 1. Smeared numerical approximations look alike and limit the possibility of a differentiated output by a neural network.

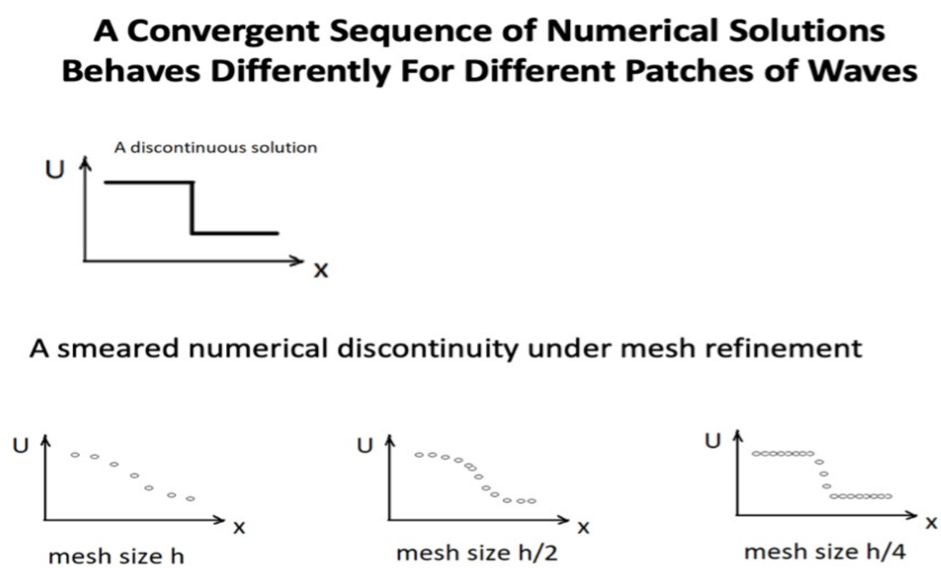

Figure 2. Modified ANN input produces more accurate reflection of discontinuity depending on the mesh refinement.

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