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Deep Learning for Turbulence Modeling

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ABSTRACT

In this paper, we provide a new artificial intelligence based deep learning Distributed Artificial Neural Network (DANN) for turbulence modeling applications, including flow past triangle, laminar flow, flow past cylinder, turbulence dynamics modeling, and flow past a real 3D product, sedan car, of real product design geometry and dimensions. The results showed six orders of magnitude speed up in computational time and need an everyday use laptop, not necessitating high end super computer servers for turbulence dynamics simulations for 3D product design industry geometries. The accuracy of the DANN use showed 99.9% accuracy and comparable to the conventional existing engineering applications software results. The DANN use software is patented and industries approved and commercially available over https://aidesign.today for product design and analysis real world product industrial use. The software is AIDesign software.

Keywords— *Turbulence modeling, Sedan car simulations, Artificial Intelligence, DANN, AIDesign*

1. INTRODUCTION

Physical quantities such as fluid flow, velocity of wind, fluid, predicted on 3D body is important in practical applications, to make and manufacture a 3D product industry for outside applications use [1]. Partial differential equation (PDE) mathematics software analysis packages are everyday used to simulate and analyse the physical laws of wind and fluid flows across 3D products in everyday application uses of humankind [2–7].

Over the last four hundred years PDEs are solved by analytical methods like separation of variables, Fourier series, finding an integral form of the solution, change of variable method to transform the equation to something that is easily solvable. FEM/FDM/CFD methods software packages are used for solving a real-world 3D product industry manufacture for humankind use for outside applications in land, water and air. However, FEM/FDM/CFD commercial software packages take long computational time and high-performance supercomputing facilities and servers and building space oftentimes few months, with 100 Tera-processors running for billions of node and server months, with space used of 6-8 acres of land use. The challenges are continued to be addressed across the globe with google making recent headlines on solving a complex pattern recognition task with revolutionary quantum computing hardware which otherwise would take 10,000 years for a summit supercomputer - the most powerful in the world today - to solve.

Deep Learning was initially introduced as an automatic feature extraction system, requiring minimum pre-processing effort by the user [8, 9]. This is an old technique that has existed from 1940 and is known by different names such as - Cybernetics and Connectionism [8]. It was reintroduced as deep learning in 2007 [9]. The sudden increase in popularity of this field was due to the development of niche algorithms for training these networks. The most popular deep learning models are Convolutional neural network (CNN) and its next developed algorithms such as Recurrent Neural Network (RNN) and Reinforcement Learning (RL) [9], which uses images to identify similarities and patterns.

2. MATHEMATICAL FORMULATION OF DEEP LEARNING FOR TURBULENCE MODELING

2.1 Distributed Artificial neural network (DANN)

The input data at each point i and for each sample, j, is trained using Distributed Artificial neural network (DANN), where the activation function is RELU function. The mathematical formulation of DANN is given below.

$$DANN = \forall \oint_{\Omega} \int_{j=1}^{M} (h_{j_i} + b_{2_i}) dj d\Omega_i \quad (1)$$

$$h_{j_i} = W_{1_i} \cdot h_{j-1_i} + W_{2_i} \cdot x_{j-1_i} + b_{1_i} \quad (2)$$

input, h_{ji} is the hidden cell state and W_{1i}, b_{1i} and W_{2i}, are the weight and bias matrices for hidden-hidden and input-hidden connections, Ω is the domain of interest, m is the number of training examples The boundary condition for each grid point i, for sample j, is denoted as b_{2i}.

2.2 DANN ALGORITHM

Here, for a given real 3D product industry use for outside applications for humankind, in land, water and air are analysed using DANN use AIDesign software. The software is patented and industries approved and commercially available over https://aidesign.today for product design and analysis real world product industrial use. The 3D industry products analysed are flow over equilateral triangle under fluid flow, in laminar conditions of real geometries of 4 m by 4 m product dimensions. Flow over cylinder application, under fluid flow, in turbulent conditions are dynamically simulated and analysed in real geometry 3D product dimensions 8 m by 4 m. Flow over a 3D sedan product car industry use under wind flow, in laminar conditions of real geometry dimension 2m by 1.5 m 3D product of industry use is simulated and analysed. The simulation results of DANN use AIDesign software showed six orders of magnitude speed up in computational time and need an everyday use laptop, not necessitating high end super computer servers for turbulence dynamics simulations for 3D product design industry geometries. The accuracy of the DANN use showed 99.9% accuracy and comparable to the conventional existing engineering applications software results. The DANN use AIDesign software is patented and industries approved and commercially available over https://aidesign.today for product design and analysis real world product industrial use.

3. RESULTS

3.1 Flow past triangle, laminar flow

Fig. 1 shows the comparison of commercial software packages vs AIDesign software package and DANN use for flow past triangle, under fluid flow in laminar conditions. The AIDesign software is patented and industries approved and commercially available over https://aidesign.today for product design and analysis real world product industrial use.

3.2 Flow past cylinder, Turbulent flow

Fig. 2 shows the comparison of commercial software packages vs AIDesign software package and DANN use for flow past cylinder, under fluid flow in turbulence dynamics conditions. The AIDesign software is patented and industries approved and commercially available over https://aidesign.today for product design and analysis real world product industrial use.

3.3 Flow past sedan car, laminar flow

Fig. 3 shows the comparison of commercial software packages vs AIDesign software package and DANN use for flow past sedan car, under wind flow in laminar conditions. The AIDesign software is patented and industries approved and commercially available over https://aidesign.today for product design and analysis real world product industrial use.

4. CONCLUSION

In this paper, we provide a new artificial intelligence based Distributed Artificial Neural Network (DANN) use for turbulence modeling applications. The results showed six orders of magnitude speed up in computational time and need an everyday use laptop, not necessitating high end super computer servers for turbulence dynamics simulations for 3D product design industry geometries. The accuracy of the DANN use showed 99.9% accuracy and comparable to the conventional existing engineering applications software results. The DANN use software is patented and industries approved and commercially available over https://aidesign.today for product design and analysis under the software name AIDesign software.

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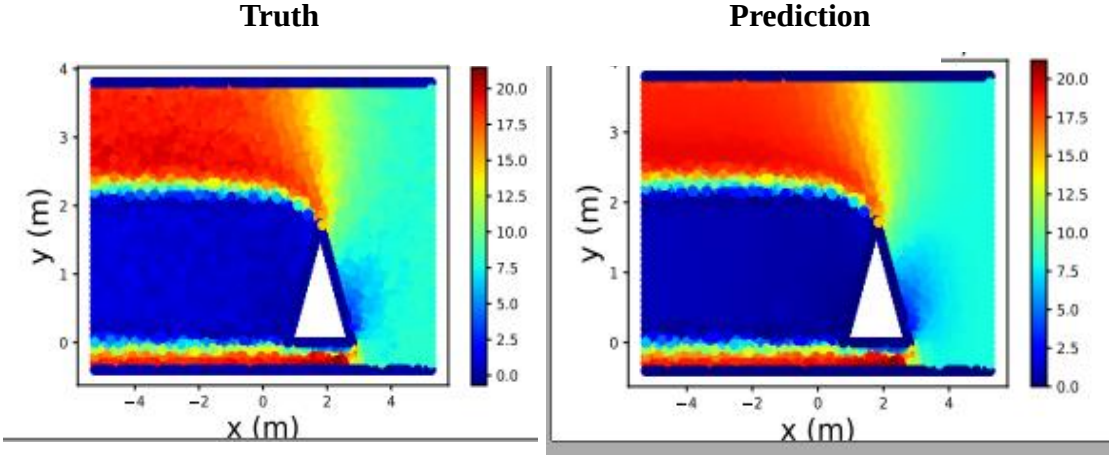

Fig. 1: Comparison of commercial software vs AIDesign, DANN intelligent result of flow past triangle, under fluid flow, in laminar conditions. AIDesign software can be accessed and downloaded and use under fee payments from https://aidesign.today

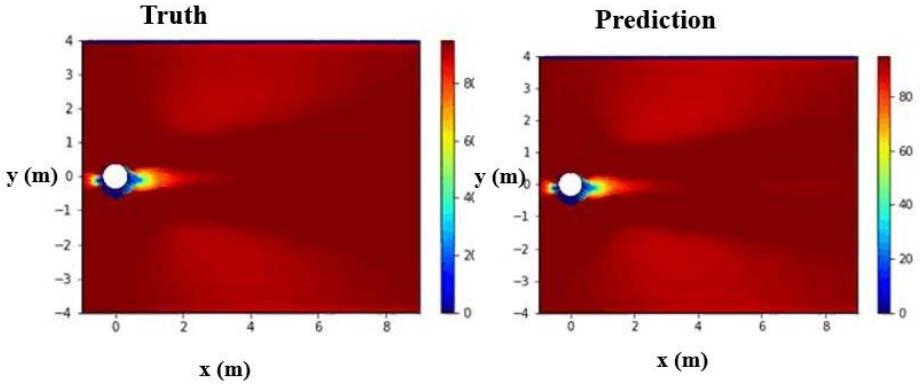

Fig. 2: Comparison of commercial software vs AIDesign, DANN intelligent result of flow past cylinder, under fluid flow in Turbulent dynamics conditions. AIDesign software can be accessed and downloaded and use under fee payments from https://aidesign.today

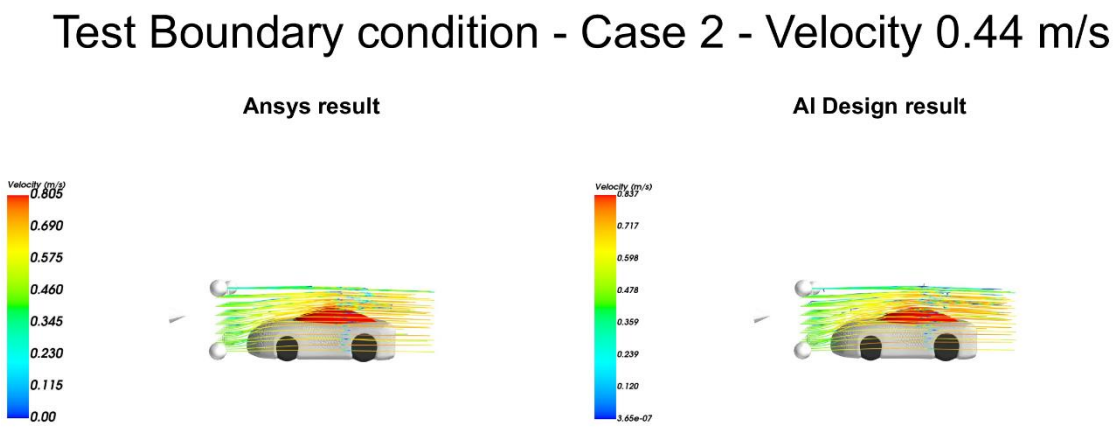

Fig. 3: Comparison of commercial software vs AIDesign, DANN intelligent result of flow past car, under wind flow in laminar condition. AIDesign software can be accessed and downloaded and use under fee payments from https://aidesign.today

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