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Editorial

Preface to the Special Issue on "Numerical Computation, Data Analysis and Software in Mathematics and Engineering"

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In recent years, mathematical models, numerical methods and data analysis have been paid more attention. After the finite element method was introduced, the meshless method became another effective tool for solving scientific and engineering problems. Numerical methods, such as the finite element method, boundary element method and meshless method, have played important roles in the numerical simulations of complicated problems in the fields of science, engineering and society. Various numerical methods have been presented for solving problems in different fields, and the corresponding computational efficiency, accuracy and convergence have been studied as well. With the development of big data, numerical simulations based on data analysis or big data will be an important direction for computation in science and engineering.

The objective of this Special Issue is to summarize the most recent developments of numerical simulations and data analysis within the last five years, especially for new problems. Many papers were submitted to this Special Issue for consideration for publication, and finally, fourteen papers were accepted after undergoing a careful peer-review process based on criteria of quality and novelty. These papers include aspects of the meshless method, numerical simulation, mathematical models, deep learning and data analysis. Meshless methods, such as the improved element-free Galerkin method, the dimension-splitting interpolating moving least-squares method, the dimension-splitting generalized interpolating element-free Galerkin method and the improved interpolating complex variable element-free Galerkin method, are presented for various problems. Some complicated problems, such as the cold roll forming process, ceramsite compound insulation blocks, crack propagation and heavy haul railway tunnels with defects are analyzed numerically. Mathematical models, such as lattice hydrodynamic models, extended car-following models and smart-helmet-based PLS-BPNN error compensation models, are proposed. Of particular note, a deep learning approach to predict the mechanical properties of a single-network hydrogel is presented, and data analysis for land leasing is discussed.

The improved element-free Galerkin (IEFG) method [1], which is based on the improved moving least-squares (IMLS) approximation [2], is an important meshless method. In the paper submitted to this Special Issue by Cheng et al. [3], the IEFG method for solving three-dimensional (3D) Helmholtz equations is proposed. The IMLS approximation is used to form the trial function, the penalty method is used to enforce the essential boundary conditions and Galerkin weak form of 3D Helmholtz equations are used to obtain the final discretized equations. The influences of the node distribution, the weight functions, the scale parameters of the influence domain and the penalty factors on the computational accuracy of the solutions are analyzed. The numerical results show that the proposed method in this paper can not only enhance the computational speed of the element-free Galerkin method but can also eliminate the phenomenon of the singular matrix.

In the paper submitted to this Special Issue by Deng et al. [4], the improved interpolating complex variable element-free Galerkin (IICVEFG) method for solving two-dimensional (2D) nonlinear elastoplasticity problems is proposed. The improved interpolating complex variable moving least-squares method, which is based on the complex variable moving least-squares approximation [5] and improved interpolating moving least-squares method [6], is used to obtain the trial function of the increment in the displacement. The integral weak form of 2D elastoplasticity problem, which is described with the increments in the displacement, stain and stress, is used to obtain the discretized equations. The incremental tangent stiffness matrix method is used to solve the discretized equations. The numerical examples show that the IICVEFG method has good convergence and high computational precision and efficiency.

The dimension-splitting method (DSM) has been introduced into meshless methods, such as the improved element-free Galerkin method [7], the improved complex variable element-free Galerkin method [8,9] and the reproducing kernel particle method [10,11], to improve computational efficiency. In the paper submitted to this Special Issue by Wang et al. [12], the DSM is combined with the improved interpolating moving least-squares (IIMLS) method based on a nonsingular weight function to propose a dimension-splitting–interpolating moving least-squares (DS-IMLS) method with high approximation accuracy. Then, an improved interpolating element-free Galerkin method for 2D potential problems is presented. In the improved interpolating element-free Galerkin method, the DS-IMLS method and the Galerkin weak form are used to obtain the discrete equations of the problem. Numerical examples show that the DS-IMLS and the improved IEFG methods have high accuracy.

In the paper submitted to this Special Issue by Sun et al. [13], by introducing the DSM into the generalized element-free Galerkin (GEFG) method, a dimension splitting generalized interpolating element-free Galerkin (DS-GIEFG) method is presented for analyzing the singularly perturbed steady convection-diffusion-reaction (CDR) problems. By using the DSM, a 2D CDR problem is transformed into a series of lower-dimensional problems. The IIMLS method is combined with the GEFG method to obtain the discrete equations on the subdivision plane. Finally, the IIMLS method is applied to assemble the discrete equations of the entire problem. Some examples are solved to verify the effectiveness of the DS-GIEFG method. The numerical results show that the numerical solution converges to the analytical solution with the decrease in node spacing, and the DS-GIEFG method has high computational efficiency and accuracy.

In recent years, big data and data analysis have been paid more and more attention. In the paper submitted to this Special Issue by Cheng [14], based on city data, the mathematical models of the price and the total area of the leased residential land are presented to analyze the leasing behavior of residential land in Beijing. The variables of the mathematical models are proposed by analyzing the factors influencing the district government's leasing behavior for residential land based on the leasing rights for residential land in Beijing. The regression formulae of the mathematical models are obtained with the ordinary least-squares method. Based on the data of the districts in Beijing from 2004 to 2015, the numerical results of the coefficients in the mathematical models are obtained. The numerical results show the factors influence the leased price and the total leased area of residential land for this large city in China, which is in agreement with the conclusion of the previous publications [15]. Finally, policy implications for the district government regarding residential land leasing in Beijing are proposed. The results of the data analysis can be referenced by the governments to make better policy.

In the paper submitted to this Special Issue by Liu et al. [16], a novel 2D lattice hydrodynamic model considering a driver's predictive effect is proposed. The stability condition of the model is obtained by performing the linear stability analysis method. The kink–antikink of the modified Korteweg–de Vries (mKdV) equation is obtained to describe the propagation characteristics of the traffic density flow waves near the critical point. The numerical results are in agreement with those of the theoretical analysis, which indicates that the predictive effect of drivers can effectively avoid traffic congestion and that the fraction of eastbound cars can also improve the stability of traffic flow to a certain extent.

In another paper submitted to this Special Issue by Liu et al. [17], a modified lattice hydrodynamic model considering the impact of strong wind and the optimal estimation of flux difference integral is proposed. Based on the control theory, the stability condition is acquired through linear analysis. The modified mKdV equation is obtained via a nonlinear analysis to express a description of the evolution of density waves. From the numerical results, it is shown that strong wind can largely influence the stability of traffic flow and that the optimal estimation of the flux difference integral contributes to stabilizing the traffic flow.

In the paper submitted to this Special Issue by Ge et al. [18], based on the visual angle model (VAM), a car-following model considering the electronic throttle angle of the preceding vehicle is proposed. The time-dependent Ginzburg–Landau (TDGL) equation and the modified mKdV equation are obtained. The numerical results are obtained by using MATLAB software to verify the validity of the model. From the numerical simulations, it is shown that the visual angle and electronic throttle can improve traffic stability.

As a kind of soft material, the large deformation of hydrogel is very complicated [19]. With the developments of deep learning and data analysis, complex network has been applied in many fields in science and engineering [20]. In the paper submitted to this Special Issue by Zhu et al. [21], based on the complex network structure of hydrogel with inhomogeneous and random distribution of polymer chains, a deep learning approach to predict the mechanical properties of hydrogels from polymer network structures is presented. The network structural models of hydrogels are constructed from the mesoscopic scale by using the self-avoiding walk method. Then, two deep learning models are proposed to capture the nonlinear mapping from mesoscopic hydrogel network structural model to its macroscale mechanical property. A deep neural network and a 3D convolutional neural network containing the physical information of the network structural model are implemented to predict the nominal stress–stretch curves of hydrogels under uniaxial tension. The results show that the deep learning models are able to capture the internal relationship between complex network structures and mechanical properties.

With the spread of COVID-19 in the world, the implementation of personnel health monitoring in construction sites has become an important problem in construction management. The paper submitted to this Special Issue by Li et al. [22] develops a smart helmet equipped with an infrared temperature sensor and conducts a simulated construction experiment to collect data of temperature and its influencing factors in indoor and outdoor construction operation environments. A partial least-square–back propagation neural network (PLS-BPNN) model is presented to correct the temperature measurement results of the smart helmet. The temperature compensation effects of different models were also compared, and the results show that the PLS-BPNN model has higher accuracy and reliability.

The paper submitted to this Special Issue by Meng et al. [23] proposes a new analytical method to predict the edge defects in the cold roll forming process based on the mean longitudinal strain of the racks. A cubic spline curve with the parameters of the cumulative chord length is applied to fit the corresponding points and center points of different passes. By comparing the mean longitudinal strain between racks and the yield strain of the material, it can be judged whether or not there are defects at the edges. The results of the analytical method are compared with the ones of the non-linear finite element software ABAQUS to show the correctness of the method. This method can predict the roll forming effect quickly and the position where a greater longitudinal strain occurred can be determined.

Peridynamics is a nonlocal theory of continuum mechanics, and it can describe crack formation and propagation without defining any fracture rules in advance. In the paper submitted to this Special Issue by Dai et al. [24], a multi-grid bond-based dual-horizon peridynamics (DH-PD) model is presented, which includes varying horizon sizes and can avoid spurious wave reflections. This model incorporates the volume correction, surface correction, and a technique of nonuniformity discretization to improve calculation accuracy and efficiency. Two benchmark problems are simulated to verify the reliability of the proposed model with the effect of the volume correction and surface correction on the computational accuracy confirmed. In addition, two numerical examples are given to verify the computational accuracy of the corrected DH-PD model and its advantages over some other models, such as the traditional peridynamics model.

In the paper submitted to this Special Issue by Fan et al. [25], the effects of different numbers of the rows and the ratios of holes on the thermal and mechanical performances of an alkali-activated slag ceramsite compound insulation block are analyzed by using the finite element analysis software ANSYS CFX. From the multi-objective optimization analysis, the alkali-activated slag ceramsite compound insulation block with the optimal comprehensive performance is determined. Finally, the improvement effect of the wall of the alkali-activated slag ceramsite compound insulation block on the indoor thermal environment relative to an ordinary block wall is analyzed.

In the paper submitted to this Special Issue by Chai [26], an elastoplastic damage constitutive model of concrete is obtained based on the basic principle of thermodynamics. The dynamic response and damage distribution of the base structure of a heavy-duty railway tunnel with defects are analyzed numerically according to the constitutive model. By analyzing the response characteristics of the tunnel basement structure under different surrounding rock softening degrees, different foundation suspension range and different foundation structure damage degree are determined. The numerical results of post-peak softening are in good agreement with the ones of the test.

As the Guest Editor of the Special Issue, I am grateful to the authors of these articles for their quality contributions, to the reviewers for their valuable comments and to the administrative staff of the MDPI publications for the support to complete this Special Issue. Special thanks to the Section Managing Editor Ms. Linn Li for her excellent collaboration and valuable assistance. I hope that these published papers will be impactful in the fields of numerical method and data analysis and that the methods in these papers will be used for solving complicated science and engineering problems.

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References

1. Zheng, G.; Cheng, Y. The Improved Element-Free Galerkin Method for Diffusional Drug Release Problems. *Int. J. Appl. Mech.* **2020**, *12*, 2050096. [CrossRef]
2. Yu, S.; Peng, M.; Cheng, H.; Cheng, Y. The improved element-free Galerkin method for three-dimensional elastoplasticity problems. *Eng. Anal. Bound. Elem.* **2019**, *104*, 215–224. [CrossRef]
3. Cheng, H.; Peng, M. The Improved Element-Free Galerkin Method for 3D Helmholtz Equations. *Mathematics* **2022**, *10*, 14. [CrossRef]
4. Deng, Y.; Shen, X.; Tao, J.; Dai, Y. Analysis of Elastic–Plastic Problems Using the Improved Interpolating Complex Variable Element Free Galerkin Method. *Mathematics* **2021**, *9*, 1967. [CrossRef]
5. Peng, M.; Liu, P.; Cheng, Y. The complex variable element-free galerkin (CVEFG) method for two-dimensional elasticity problems. *Int. J. Appl. Mech.* **2009**, *1*, 367–385. [CrossRef]
6. Ren, H.; Cheng, Y. The interpolating element-free galerkin (IEFG) method for two-dimensional elasticity problems. *Int. J. Appl. Mech.* **2011**, *3*, 735–758. [CrossRef]
7. Meng, Z.J.; Cheng, H.; Ma, L.D.; Cheng, Y.M. The hybrid element-free Galerkin method for three-dimensional wave propagation problems. *Int. J. Numer. Methods Eng.* **2019**, *117*, 15–37. [CrossRef]
8. Cheng, H.; Peng, M.; Cheng, Y. A Fast Complex Variable Element-Free Galerkin Method for Three-Dimensional Wave Propagation Problems. *Int. J. Appl. Mech.* **2017**, *9*, 1750090. [CrossRef]
9. Cheng, H.; Peng, M.; Cheng, Y. The dimension splitting and improved complex variable element-free Galerkin method for 3-dimensional transient heat conduction problems. *Int. J. Numer. Methods Eng.* **2018**, *114*, 321–345. [CrossRef]
10. Peng, P.; Wu, Q.; Cheng, Y. The dimension splitting reproducing kernel particle method for three-dimensional potential problems. *Int. J. Numer. Methods Eng.* **2020**, *121*, 146–164. [CrossRef]
11. Peng, P.; Fu, Y.; Cheng, Y. A Hybrid Reproducing Kernel Particle Method for Three-Dimensional Advection-Diffusion Problems. *Int. J. Appl. Mech.* **2021**, *13*, 2150085. [CrossRef]

12. Wang, J.; Sun, F.; Cheng, R. A Dimension Splitting-Interpolating Moving Least Squares (DS-IMLS) Method with Nonsingular Weight Functions. *Mathematics* **2021**, *9*, 2424. [CrossRef]
13. Sun, F.; Wang, J.; Kong, X.; Cheng, R. A Dimension Splitting Generalized Interpolating Element-Free Galerkin Method for the Singularly Perturbed Steady Convection–Diffusion–Reaction Problems. *Mathematics* **2021**, *9*, 2524. [CrossRef]
14. Cheng, J. Mathematical Models and Data Analysis of Residential Land Leasing Behavior of District Governments of Beijing in China. *Mathematics* **2021**, *9*, 2314. [CrossRef]
15. Cheng, J.; Luo, X. Analyzing the Land Leasing Behavior of the Government of Beijing, China, via the Multinomial Logit Model. *Land* **2022**, *11*, 376. [CrossRef]
16. Liu, H.; Cheng, R.; Xu, T. Analysis of a Novel Two-Dimensional Lattice Hydrodynamic Model Considering Predictive Effect. *Mathematics* **2021**, *9*, 2464. [CrossRef]
17. Liu, H.; Wang, Y. Impact of Strong Wind and Optimal Estimation of Flux Difference Integral in a Lattice Hydrodynamic Model. *Mathematics* **2021**, *9*, 2897. [CrossRef]
18. Ge, H.; Li, S.; Yan, C. An Extended Car-Following Model Based on Visual Angle and Electronic Throttle Effect. *Mathematics* **2021**, *9*, 2879. [CrossRef]
19. Liu, Z.; Toh, W.; Ng, T.Y. Advances in Mechanics of Soft Materials: A Review of Large Deformation Behavior of Hydrogels. *Int. J. Appl. Mech.* **2015**, *7*, 1530001. [CrossRef]
20. Cheng, J.; Xie, Y.; Zhang, J. Industry structure optimization via the complex network of industry space: A case study of Jiangxi Province in China. *J. Clean. Prod.* **2022**, *338*, 130602. [CrossRef]
21. Zhu, J.-A.; Jia, Y.; Lei, J.; Liu, Z. Deep Learning Approach to Mechanical Property Prediction of Single-Network Hydrogel. *Mathematics* **2021**, *9*, 2804. [CrossRef]
22. Li, L.; Yu, J.; Cheng, H.; Peng, M. A Smart Helmet-Based PLS-BPNN Error Compensation Model for Infrared Body Temperature Measurement of Construction Workers during COVID-19. *Mathematics* **2021**, *9*, 2808. [CrossRef]
23. Meng, Z.; Fang, Y.; Ma, L. A Method for Rapid Prediction of Edge Defects in Cold Roll Forming Process. *Mathematics* **2021**, *9*, 1902. [CrossRef]
24. Dai, Z.; Xie, J.; Lu, Z.; Qin, S.; Wang, L. Numerical Modeling on Crack Propagation Based on a Multi-Grid Bond-Based Dual-Horizon Peridynamics. *Mathematics* **2021**, *9*, 2848. [CrossRef]
25. Fan, X.; Guo, Y.; Zhao, Q.; Zhu, Y. Structural Optimization and Application Research of Alkali-Activated Slag Ceramsite Compound Insulation Block Based on Finite Element Method. *Mathematics* **2021**, *9*, 2488. [CrossRef]
26. Chai, J. Research on Dynamic Response Characteristics for Basement Structure of Heavy Haul Railway Tunnel with Defects. *Mathematics* **2021**, *9*, 2893. [CrossRef]