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Research Article

Simulating New CKO as a Model of Seismic Sea Waves via Unified Solver

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Due to high rate of electrical device usage of all types and high consumption of electricity, it is necessary to search for alternative way. There are so many models of nature describing many phenomena in energy, magnetic field, heat transfer, and so on. These models are reflected in the delicate nonlinear partial differential equations. The system of coupled Konno-Oono equations is one of those models. We extract some vital solutions for this model, which describe some vital phenomena in applied science. Namely, we applied unified technique in order to perform this mechanism in a completely unified way. Finally, some simulations are performed by utilizing Matlab 18 to exhibit the behaviour of these solutions.

1. Introduction

Nonlinear partial differential equations (NPDEs) have been the most extensively researched subject of comprehensive studies in a variety of real-world challenges such as energy, solid-state physics, soil-structure interaction analysis, optical fiber communications, chemical engineering, propagation of shallow water waves, plasma physics, chemical kinematics, and heat transfer [1–7]. The solutions of the NPDEs are of great importance for the scientists; namely, these solutions describe natural complex phenomena for the nonlinear event. Because of the difficulty of the NPDEs, there is no consolidated approach to get all solutions of these equations. Thus, there are so many methods that have been presented by diverse groups of physicists and mathematicians; see, for example, [8–15].

Tsunami and ocean acoustic wave fields generated by tremors along Japan's coast in 2011, most of which were connected to short-distance seismic happenings (tremors from Mw 6.9 to 8.8 Mw), have been noticed by the world [16]. Actually, the research of Chunga and Toulkeridis [17] was introducing the first signs of natural disasters, where the wavelength range and height of seismic sea waves are very notable. The authors' work uses a stiffness-eccentric structural model that has been numerically validated to explore the impact of various seismic orientations on the statistical distribution of nonlinear seismic response [18]. Distributed optical fiber acoustic sensing (DAS), which has recently gained popularity, is thought to revolutionize seismic exploration [19]. Due to high rate of electrical device usage of all kinds and high consumption of electricity, it is necessary to improve the efficiency of these devices. Thus, the massive power can be converted to renewable energy sources to provide the necessary energy for buildings, namely, the use of renewable energy sources such as solar energy and wind energy to provide the required energy to operate these devices in buildings or reduce their traditional energy consumption. This mechanism will be necessary and so vital in the future to contain the enormity of the tragedy. The Wiener process is used to quantify random changes in water depth, which can better characterize the situation in which water depths change in a nonmonotonic manner [20]. On the other hand, the new features of nonlinear models of ocean waves become one of the most important topics for much science research [21, 22].

The coupled Konno-Oono (CKO) model is defined as follows [23]:

$$\begin{aligned} &\phi_{xt} - 2\alpha\phi\,\chi_{xx} - 2\beta\phi\,\psi_x + \gamma(\chi\psi)_x = 0, \\ &\chi_{xt} - 2\alpha\chi\,\chi_x - 2\beta(2\phi\phi_x + \chi_x\psi) - 2\gamma(\phi)_x\chi = 0, \\ &\psi_{xt} - 2\beta\psi\,\psi_x - 2\alpha(2\phi\phi_x + \chi\psi_x) - 2\gamma\psi(\phi)_x = 0, \end{aligned} \tag{1}$$

where α, β, and γ are constants. Equation (1) has been taken into account as an application for current-filed strings interacting with an external magnetic field [23–25], as well as the parallel transport of each curve point along the direction of time where the connection is magnetically valued [26]. When some coefficients in Equation (1) are given special values, this model transformed into a new Konno-Oono system, that is, a coupled integrable dispersionless equations presented as follows [23]:

$$\begin{aligned} &v_{xt} - 2v\,u = 0, \\ &u_t + 2v\,v_x = 0. \end{aligned} \tag{2}$$

Recently, this model has attracted a special attention and has been the subject of many studies, such as the ETEM [27], tanh function and extended tanh function methods [28], sine-Gordon expansion approach [29], new extended direct algebraic approach [30], modified simple equation method [31], and extended exp-function method [16].

In [32], we introduced a consolidated solver approach to solve NFPDE, based on He's semi-inverse principle [33–35]. This method provides the complete structure of waves of various kinds of NFPDEs. It is also straightforward, sturdy, and efficient. The proposed approach offers several benefits, including the avoidance of complicated and time-consuming computations and the provision of precise solutions. In the current work, we applied this solver to grasp some new solitary waves for the new CKO model. The obtained results are valid in the dramatic and critical points that may appear in huge or explosive waves, which can propagate in oceanic engineering, physics, and other disciplines. To our knowledge, no previous research has been done utilizing this technique. Our study shows the adequacy of the proposed approach to consider other models emerging in applied sciences.

The outline of this study is arranged as follows: Section 2 presents the proposed technique. Section 3 introduces some new solitary waves of the new CKO model. Section 4 describes the physical interpretation for the gained results. We also introduce several graphs to depict the behaviour of presented solutions. Finally, Section 5 gives a conclusion remark about the acquired results.

2. Solver Technique

Let us consider the NLPDEs

$$\Gamma(\Xi, \Xi_x, \Xi_t, \Xi_{xx}, \Xi_{xt}, \Xi_{tt}, \cdots) = 0. \tag{3}$$

Utilizing the suitable wave transformation,

$$\Xi(x, t) = \Xi(\xi), \quad \xi = x - \mu\, t, \tag{4}$$

where μ is the velocity of the wave. Equation (3) is transferred to the following ODE:

$$\Lambda\left(\Xi, \Xi', \Xi'', \Xi''', \cdots\right) = 0. \tag{5}$$

Many models in applied sciences of the form (3) are converted to the following ODE:

$$L\Xi'' + M\Xi^3 + N\Xi = 0, \tag{6}$$

where L, M, and N are certain constants based on the constants of the main model and the speed of wave.

The solutions of Equation (6) are given by the unified approach [32].

2.1. Family 1. The first family of solutions is

$$\Xi(\xi) = \pm\sqrt{\frac{-2N}{M}}\,\mathrm{sech}\left(\pm\sqrt{-\frac{N}{L}}\xi\right). \tag{7}$$

2.2. Family 2. The second family of solutions is

$$\Xi(\xi) = \pm\sqrt{\frac{-35\,N}{18\,M}}\,\mathrm{sech}^2\left(\pm\sqrt{-\frac{5\,N}{12\,L}}\,\xi\right). \tag{8}$$

2.3. Family 3. The third family of solutions is

$$\Xi(\xi) = \pm\sqrt{\frac{-N}{M}}\,\tanh\left(\pm\sqrt{\frac{N}{L}}\xi\right). \tag{9}$$

3. Solutions of New CKO Model

The travelling wave transformation (2)

$$\begin{aligned} &v(x, t) = V(\xi), \xi = k(x - \mu\, t), \\ &u(x, t) = U(\xi), \xi = k(x - \mu\, t) \end{aligned} \tag{10}$$

converts (2) into the following system of ordinary differential equations:

$$-\mu\, k^2 V'' - 2VU = 0, \tag{11}$$

$$-\mu\, kU' + 2kVV' = 0, \tag{12}$$

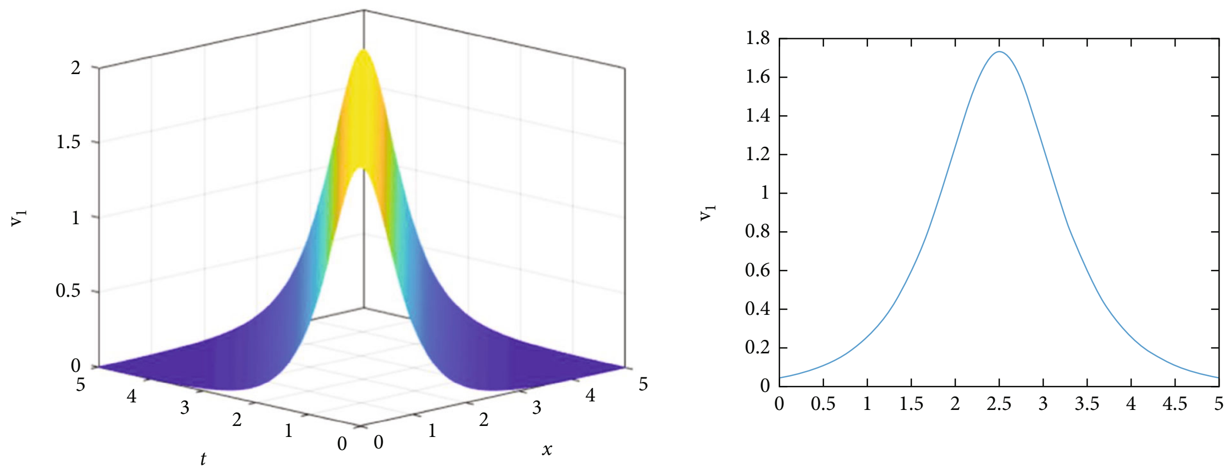

FIGURE 1: 3D and 2D plots of v_1.

where k is the wave number and μ is the wave velocity. Integrating Equation (12) yields

$$U = \frac{1}{\mu}\left(V^2 + c\right), \tag{13}$$

where c is the integration constant. Setting Equation (13) into Equation (11) gives

$$\mu^2 k^2 V'' + 2V^3 + 2c\, V = 0. \tag{14}$$

The solutions of Equation (2) are as follows:
Family 1:

$$v_{1,2}(x,t) = \pm\sqrt{-2c}\ \operatorname{sech}\left(\pm\frac{\sqrt{-2c}}{\mu}(x-\mu t)\right), \tag{15}$$

$$u_{1,2}(x,t) = \frac{c}{\mu}\left(1 - 2\ \operatorname{sech}^2\left(\pm\frac{\sqrt{-2c}}{\mu}(x-\mu t)\right)\right). \tag{16}$$

Family 2:

$$\begin{aligned} v_{3,4}(x,t) &= \pm\sqrt{\frac{-35\,c}{18}}\ \operatorname{sech}^2\left(\pm\frac{\sqrt{-5\,c}}{\sqrt{6}\,\mu}(x-\mu t)\right),\\ u_{3,4}(x,t) &= \frac{c}{\mu}\left(1 - \frac{35}{18}\ \sec h^4\left(\pm\frac{\sqrt{-5\,c}}{\sqrt{6}\,\mu}(x-\mu t)\right)\right). \end{aligned} \tag{17}$$

Family 3:

$$v_{5,6}(x,t) = \pm\sqrt{-c}\ \tanh\left(\pm\frac{\sqrt{c}}{\mu}(x-\mu t)\right), \tag{18}$$

$$u_{5,6}(x,t) = \frac{c}{\mu}\left(1 - \tanh^2\left(\pm\frac{\sqrt{c}}{\mu}(x-\mu t)\right)\right). \tag{19}$$

4. Results and Discussion

We aim to explain the applications of the presented solutions. We have derived some new vital solutions for the CKO model, utilizing unified technique. Namely, we introduce some hyperbolic solutions in explicit way. The proposed method has the essential benefit over the majority of existing methods in that it provides more free parameters in addition to some crucial exact solutions. This strategy is unambiguous, direct, easy, and effective. Indeed, the proposed approach can be utilized as a box solver for physicists, mathematicians, and engineers. In fact, it provides several soliton wave solutions that characterize various magnetic field occurrences.

Furthermore, the presented hyperbolic solutions are of different physical meanings as well. Namely, these solutions preserve some important physical meanings and explain vital complex phenomena as well. For example, hyperbolic secant solutions emerge in the profile of a laminar jet [36], whereas hyperbolic tangent solutions protrude in magnetic moment and special relativity.

Seismic waves are acoustic energy waves that flow through the Earth. The authors in [37] analyzed the seismic performance of the unsaturated soil slope. The authors in [38] proposed a numerical technique for modelling the seismic behavior of a wind turbine on a monopile foundation to examine the seismic execution of a wind turbine that is affected by both the seismic load and the ice load. The authors in [39] used physics-informed Caianiello convolutional neural networks to perform a seismic inversion for overpressure prediction. On the other hand, the hyperbolic solitary wave solutions (15)-(19) describe the ranges and elevations of seismic sea waves as illustrated in Figures 1–6. Figures 1, 3, and 6 depict the soliton wave with high dispersion (bell shaped). Figure 2 depicts the soliton wave with low dispersion. Figure 4 depicts the negative soliton wave.

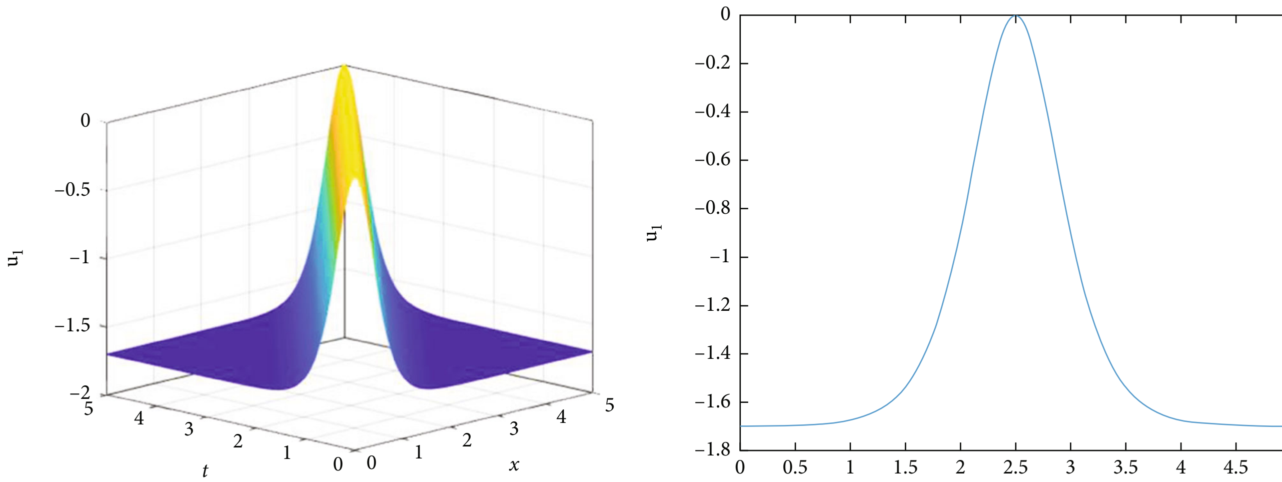

Figure 2: 3D and 2D plots of u_1.

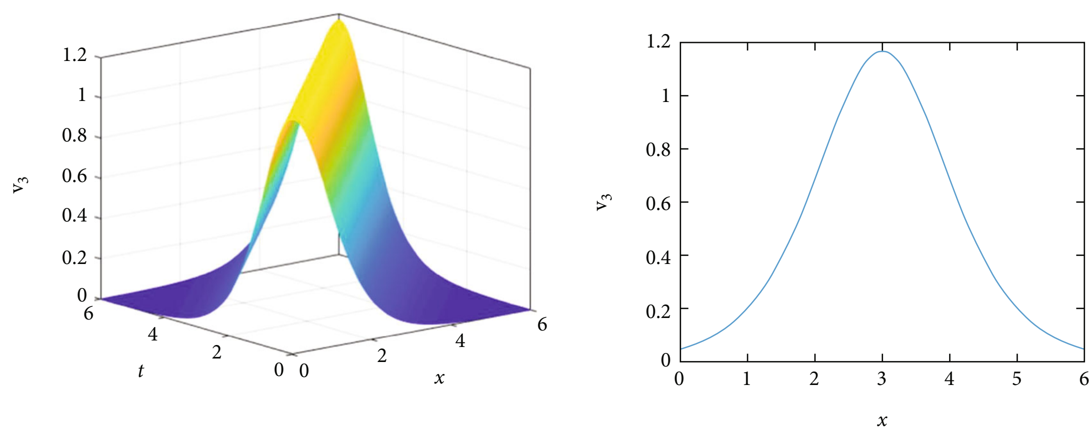

Figure 3: 3D and 2D plots of v_3.

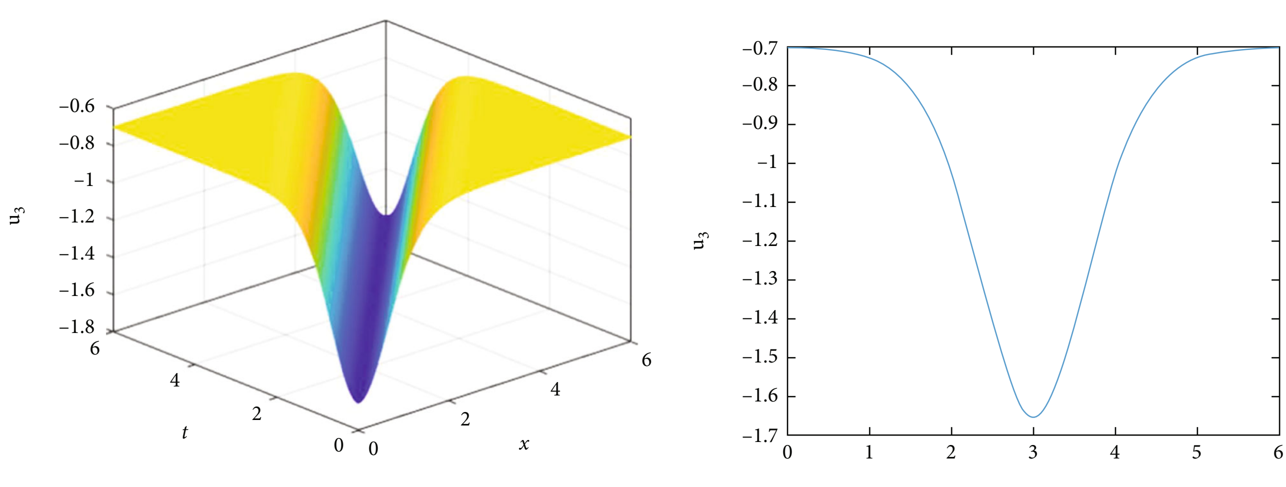

Figure 4: 3D and 2D plots of u_3.

Figure 5 depicts the kink wave. Actually, if the amplitudes of these waves are so large, they would be more dangerous to the entire world. One of the main important mechanisms in applied science is to reduce the disastrous force of such huge natural disasters or to transform them to renewable energy. This mechanism will reduce the energy

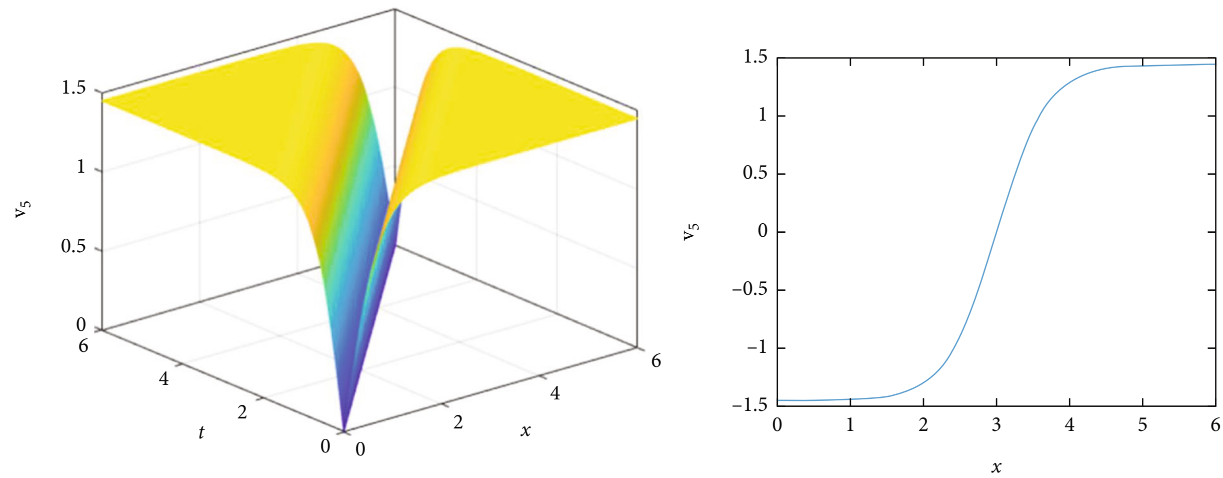

Figure 5: 3D and 2D plots of v_5.

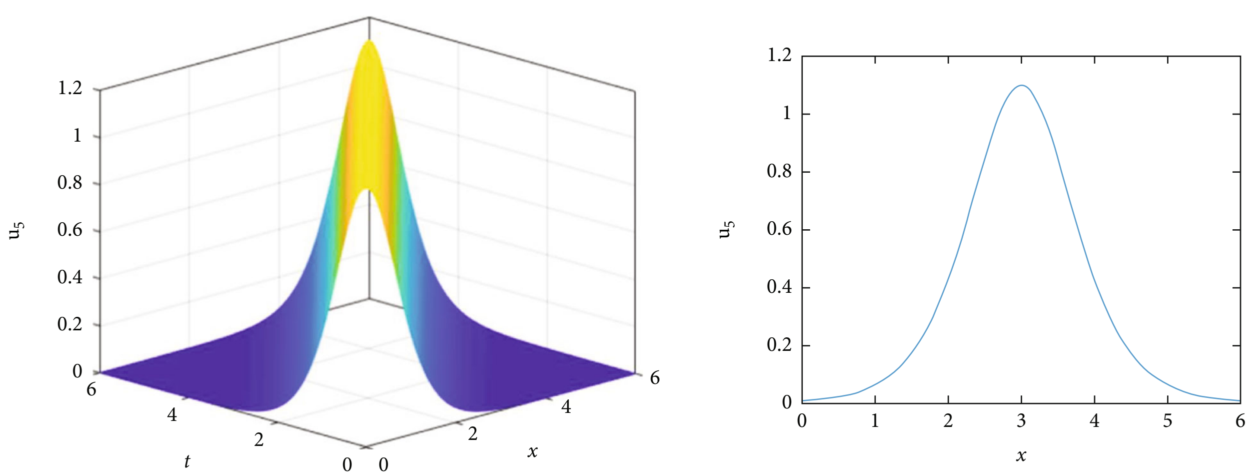

Figure 6: 3D and 2D plots of u_5.

consumption of buildings. Indeed, this technique will be very beneficial for many countries, which specifically face the seismic sea wave phenomena. In order to perform this mechanism, one should consider the mathematical frameworks of such natural problems. The best method to understand such tragedies is to address them by utilizing different techniques and taking the appropriate safety procedures.

5. Conclusions

In this paper, we have constructed some vital solitary wave solutions for the CKO model. Namely, we implemented the unified solver to solve this model. This solver introduced closed form solutions for scientific models. The proposed solver has various advantages, including avoiding difficult and time-consuming computations and providing precise results through physical parameters. Many engineers, physicists, and mathematicians will use this solver as a box tool due to its efficiency and accuracy. By controlling the seismic sea wave phenomena, one can produce a renewable energy, which may contribute significantly to the provision of a clean electrical energy source. Finally, the proposed approach can also be implemented to other complex models, and therefore, we shall take it up in our future works.

Data Availability

All the data are available within the article.

Conflicts of Interest

The authors have no conflicts of interest regarding the publication of this paper.

Authors' Contributions

All the authors have equal contributions in this article.

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