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On certain new integrable second order nonlinear differential equations and their connection with two dimensional Lotka-Volterra system

R. Gladwin Pradeep, V.K. Chandrasekar, M. Senthilvelan, M. Lakshmanan

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In this paper, we consider a second order nonlinear ordinary differential equation of the form $\ddot{x}+k_1\frac{\dot{x}^2}{x}+(k_2+k_3x)\dot{x} +k_4x^3+k_5x^2+k_6x=0$, where k_i's, $i=1,2,...,6,$ are arbitrary parameters. By using the modified Prelle-Singer procedure, we identify five new integrable cases in this equation besides two known integrable cases, namely (i) $k_2=0, k_3=0$ and (ii) $k_1=0, k_2=0, k_5=0$. Among these five, four equations admit time dependent first integrals and the remaining one admits time independent first integral. From the time independent first integral, nonstandard Hamiltonian structure is deduced thereby proving the Liouville sense of integrability. In the case of time dependent integrals, we either explicitly integrate the system or transform to a time-independent case and deduce the underlying Hamiltonian structure. We also demonstrate that the above second order ordinary differential equation is intimately related to the two-dimensional Lotka-Volterra (LV) system. From the integrable parameters of above nonlinear equation and all the known integrable cases of the latter can be deduced thereby.

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