

Nonlocal Symmetries of Nonlinear Integrable Models

Xing-Biao HU[†] and Sen-Yue LOU[‡]

[†] *State Key Laboratory of Scientific and Engineering Computing,
Institute of Computational Mathematics and Scientific Engineering Computing,
Academia Sinica, P.O. Box 2719, Beijing 100080, P.R. China*

[‡] *CCAST (World Laboratory), P.O. Box 8730, Beijing 100080, P.R. China
Institute of Modern Physics, Ningbo Normal College, Ningbo 315211, P.R. China*

In this paper, nonlocal symmetries are considered for some integrable equations including the first equation of the AKNS hierarchy, the so-called breaking soliton equation, the Boussinesq equation and the Toda equation. Besides, using invariant transformations of corresponding spectral problems, more nonlocal symmetries can be produced from one seed symmetry.

1 Introduction

Symmetries and conservation laws for differential equations are the central themes of perpetual interest in mathematical physics. During past thirty years, the study of symmetries has been connected with the development of soliton theory and, in fact, it constitutes an indispensable and important part of soliton theory.

Let us begin with the celebrated Korteweg de Vries equation

$$u_t + 6uu_x + u_{xxx} = 0, \quad (1)$$

where the subscripts represent derivatives. A symmetry of the KdV equation (1) is defined as a solution of its linearized equation

$$\sigma_t + 6(u\sigma)_x + \sigma_{xxx} = 0. \quad (2)$$

It is well known that x -translation and t -translation invariance of (1) leads to the following symmetries: u_x , u_t of the KdV equation (1). In order to find more generalized symmetries, the concepts of recursion operators or strong symmetries, and hereditary symmetries were introduced by Olver and Fuchssteiner and used to find these symmetries [1, 2]. Furthermore, Galilean invariance of the KdV equation (1) leads to symmetry $u_x - \frac{1}{6}$, which may be viewed as the origin of active research on the time-dependent symmetries and the corresponding Lie algebraic structures for nonlinear equations; and these time-dependent symmetries are connected with nonisospectral problems (see, e.g. [3–6]). Apart from the symmetries mentioned above, there exist so-called nonlocal symmetries expressed by spectral functions, e.g., $\sigma = (\phi^2)_x$ is a symmetry of the KdV equation (1), where ϕ is a spectral function of Lax pair

$$\phi_{xx} + u\phi = \lambda\phi, \quad (3)$$

$$\phi_t = u_x\phi - (2u + 4\lambda)\phi_x. \quad (4)$$

To search for nonlocal symmetries is an interesting topic. On one hand, these nonlocal symmetries enlarge class of symmetries. Besides, nonlocal symmetries are connected with integrable models. Such an example is the nonlocal symmetry $\sigma = (\phi^2)_x$ generates well-known sinh-Gordon

New Symmetries And Integrable Models

Richard Kerner



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Proceedings of XIV Max Born Symposium, New Symmetries and Integrable Models Andrzej Frydryszak, Jerzy Lukierski, Z. Popowicz, 2000 The Max Born Symposia started in 1991 and have been held once or twice a year in different places in Lower Silesia The scientific topics of the Symposia are closely related with front line research subjects in theoretical physics This volume deals with new concepts of symmetries in the theory of fundamental interactions as well as integrable dynamical systems *Nonlinear Systems and Their Remarkable Mathematical Structures* Norbert Euler, Da-jun Zhang, 2021-09-06 The third volume in this sequence of books consists of a collection of contributions that aims to describe the recent progress in nonlinear differential equations and nonlinear dynamical systems both continuous and discrete *Nonlinear Systems and Their Remarkable Mathematical Structures Volume 3 Contributions from China* just like the first two volumes consists of contributions by world leading experts in the subject of nonlinear systems but in this instance only featuring contributions by leading Chinese scientists who also work in China in some cases in collaboration with western scientists Features Clearly illustrate the mathematical theories of nonlinear systems and its progress to both the non expert and active researchers in this area Suitable for graduate students in Mathematics Applied Mathematics and some of the Engineering Sciences Written in a careful pedagogical manner by those experts who have been involved in the research themselves and each contribution is reasonably self contained **Geometry of Integrable Systems** Alessandro Arsie, Igor Mencattini, 2026-02-10 This textbook explores differential geometrical aspects of the theory of completely integrable Hamiltonian systems It provides a comprehensive introduction to the mathematical foundations and illustrates it with a thorough analysis of classical examples This book is organized into two parts Part I contains a detailed elementary exposition of the topics needed to start a serious geometrical analysis of complete integrability This includes a background in symplectic and Poisson geometry the study of Hamiltonian systems with symmetry a primer on the theory of completely integrable systems and a presentation of bi Hamiltonian geometry Part II is devoted to the analysis of three classical examples of integrable systems This includes the description of the free n dimensional rigid body the rational Calogero Moser system and the open Toda system In each case the system is described its integrability is discussed and at least one of its known bi Hamiltonian descriptions is presented This work can benefit advanced undergraduate and beginning graduate students with a strong interest in geometrical methods of mathematical physics Prerequisites include an introductory course in differential geometry and some familiarity with Hamiltonian and Lagrangian mechanics Mathematical Reviews ,2002 Models of Agglomeration and Glass Transition Richard Kerner, 2007 This book is for any physicist interested in new vistas in the domain of non crystalline condensed matter aperiodic and quasi crystalline networks and especially glass physics and chemistry Students with an elementary background in thermodynamics and statistical physics will find the book accessible The physics of glasses is extensively covered focusing on their thermal and mechanical properties as well as various models leading to the

formation of the glassy states of matter from overcooled liquids The models of agglomeration and growth are also applied to describe the formation of quasicrystals fullerenes and in biology to describe virus assembly pathways

Emerging Frontiers in Nonlinear Science Panayotis G. Kevrekidis, Jesús Cuevas-Maraver, Avadh Saxena, 2020-05-29 This book explores the impact of nonlinearity on a broad range of areas including time honored fields such as biology geometry and topology but also modern ones such as quantum mechanics networks metamaterials and artificial intelligence The concept of nonlinearity is a universal feature in mathematics physics chemistry and biology and is used to characterize systems whose behavior does not amount to a superposition of simple building blocks but rather features complex and often chaotic patterns and phenomena Each chapter of the book features a synopsis that not only recaps the recent progress in each field but also charts the challenges that lie ahead This interdisciplinary book presents contributions from a diverse group of experts from various fields to provide an overview of each field's past present and future It will appeal to both beginners and seasoned researchers in nonlinear science numerous areas of physics optics quantum physics biophysics and applied mathematics ODEs PDEs dynamical systems machine learning as well as engineering

Aspects of Integrability of Differential Systems and Fields Costas J. Papachristou, 2020-01-01 This book serves as an introduction to the concept of integrability as it applies to systems of differential equations as well as to vector valued fields The author focuses on specific aspects of integrability that are often encountered in a variety of problems in applied mathematics physics and engineering The following general cases of integrability are examined a path independence of line integrals of vector fields on the plane and in space b integration of a system of ordinary differential equations by using first integrals and c integrable systems of partial differential equations Special topics include the integration of analytic functions and some elements from the geometric theory of differential systems Certain more advanced subjects such as Lax pairs and Bäcklund transformations are also discussed The book is written at an intermediate level for educational purposes The presentation is as simple as the topics allow often sacrificing mathematical rigor in favor of pedagogical efficiency

Soliton Theory and Its Applications Chaohao Gu, 2013-03-14 Soliton theory is an important branch of applied mathematics and mathematical physics An active and productive field of research it has important applications in fluid mechanics nonlinear optics classical and quantum fields theories etc This book presents a broad view of soliton theory It gives an expository survey of the most basic ideas and methods such as physical background inverse scattering Bäcklund transformations finite dimensional completely integrable systems symmetry Kac-Moody algebra solitons and differential geometry numerical analysis for nonlinear waves and gravitational solitons Besides the essential points of the theory several applications are sketched and some recent developments partly by the authors and their collaborators are presented

Journal of the Physical Society of Japan Nihon Butsuri Gakkai, 2000

Advances in Nonlinear Dynamics Walter Lacarbonara, Balakumar Balachandran, Michael J. Leamy, Jun Ma, J. A. Tenreiro Machado, Gabor Stepan, 2022-03-18 This first of three volumes includes papers from the second

series of NODYCON which was held virtually in February of 2021 The conference papers reflect a broad coverage of topics in nonlinear dynamics ranging from traditional topics from established streams of research to those from relatively unexplored and emerging venues of research These include Fluid structure interactions Mechanical systems and structures Computational nonlinear dynamics Analytical techniques Bifurcation and dynamic instability Rotating systems Modal interactions and energy transfer Nonsmooth systems Meetings on Atomic Energy ,1999 **Physics Briefs** ,1993 Acta Physica Sinica ,1997 *Reviews in Partial Differential Equations, 1980-86, as Printed in Mathematical Reviews* ,1988 **General physics, relativity, astronomy and mathematical physics and methods** ,1995 **Physics Letters** ,1999 **High Energy Physics Index** ,1994 **Journal of Physics A** ,1999 Focuses on fundamental mathematical and computational methods underpinning physics Relevant to statistical physics chaotic and complex systems classical and quantum mechanics classical and quantum integrable systems and classical and quantum field theory XV International Colloquium on Group Theoretical Methods in Physics, October 20-24, 1986, Drexel University, Philadelphia, PA Robert Gilmore,1987 **Balkan Journal of Geometry and Its Applications** ,2004

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