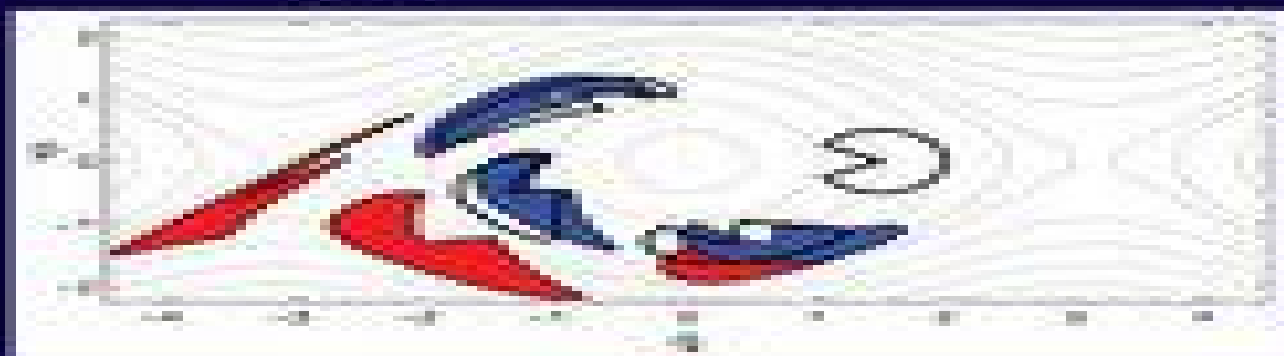


# A Concise Introduction to Geometric Numerical Integration



Sergio Blanes  
Fernando Casas

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A CHAPMAN & HALL BOOK

# Geometric Numerical Integration Geometric Numerical Integration

**Erwan Faou**



## **Geometric Numerical Integration Geometric Numerical Integration:**

*Geometric Numerical Integration* Ernst Hairer, Christian Lubich, Gerhard Wanner, 2006-05-18 This book covers numerical methods that preserve properties of Hamiltonian systems reversible systems differential equations on manifolds and problems with highly oscillatory solutions It presents a theory of symplectic and symmetric methods which include various specially designed integrators as well as discusses their construction and practical merits The long time behavior of the numerical solutions is studied using a backward error analysis combined with KAM theory [A Concise Introduction to Geometric Numerical Integration](#) Sergio Blanes, Fernando Casas, 2017-11-22 Discover How Geometric Integrators Preserve the Main Qualitative Properties of Continuous Dynamical Systems A Concise Introduction to Geometric Numerical Integration presents the main themes techniques and applications of geometric integrators for researchers in mathematics physics astronomy and chemistry who are already familiar with numerical tools for solving differential equations It also offers a bridge from traditional training in the numerical analysis of differential equations to understanding recent advanced research literature on numerical geometric integration The book first examines high order classical integration methods from the structure preservation point of view It then illustrates how to construct high order integrators via the composition of basic low order methods and analyzes the idea of splitting It next reviews symplectic integrators constructed directly from the theory of generating functions as well as the important category of variational integrators The authors also explain the relationship between the preservation of the geometric properties of a numerical method and the observed favorable error propagation in long time integration The book concludes with an analysis of the applicability of splitting and composition methods to certain classes of partial differential equations such as the Schrödinger equation and other evolution equations The motivation of geometric numerical integration is not only to develop numerical methods with improved qualitative behavior but also to provide more accurate long time integration results than those obtained by general purpose algorithms Accessible to researchers and post graduate students from diverse backgrounds this introductory book gets readers up to speed on the ideas methods and applications of this field Readers can reproduce the figures and results given in the text using the MATLAB programs and model files available online *Geometric Numerical Integration* Ernst Hairer, Christian Lubich, Gerhard Wanner, 2006-02-22 This book covers numerical methods that preserve properties of Hamiltonian systems reversible systems differential equations on manifolds and problems with highly oscillatory solutions It presents a theory of symplectic and symmetric methods which include various specially designed integrators as well as discusses their construction and practical merits The long time behavior of the numerical solutions is studied using a backward error analysis combined with KAM theory **Geometric Numerical Integration** Ernst Hairer, Christian Lubich, Gerhard Wanner, 2006 Provides information on numerical methods that preserve properties of Hamiltonian systems reversible systems differential equations on manifolds and problems with highly oscillatory solutions This book presents a theory of symplectic

and symmetric methods including composition splitting multistep and various specially designed integrators *Geometric Numerical Integration* Pui Sze Priscilla Tse, 2007 This result implies that B series methods cannot preserve both volume and affine symmetries simultaneously for arbitrary systems Lastly we present a new fourth order method which is symplectic self adjoint and preserves the exact linearization at fixed points of an arbitrary Hamiltonian system This method is based on the preprocessed vector field integrators which is the concept of integrating a preprocessed version of the original vector field as opposed to direct integration We find numerically that for certain Hamiltonian systems the global truncation error grows more slowly for this new preprocessed integrator than for other fourth order integrators such as the non symplectic Runge Kutta method and the symplectic and self adjoint Gauss method *Geometric Numerical Integration of Differential Equations* Reinout Quispel, Robert McLachlan, 2006

**Geometric Numerical Integration and Schrödinger Equations** Erwan Faou, 2012 The goal of geometric numerical integration is the simulation of evolution equations possessing geometric properties over long periods of time Of particular importance are Hamiltonian partial differential equations typically arising in application fields such as quantum mechanics or wave propagation phenomena They exhibit many important dynamical features such as energy preservation and conservation of adiabatic invariants over long periods of time In this setting a natural question is how and to which extent the reproduction of such long time qualitative behavior can be ensured by numerical schemes Starting from numerical examples these notes provide a detailed analysis of the Schrodinger equation in a simple setting periodic boundary conditions polynomial nonlinearities approximated by symplectic splitting methods Analysis of stability and instability phenomena induced by space and time discretization are given and rigorous mathematical explanations are provided for them The book grew out of a graduate level course and is of interest to researchers and students seeking an introduction to the subject matter **Special Issue on Geometric Numerical Integration of Differential Equations**, 2006 **Geometric Numerical Integration for Optimisation** Erlend Skaldehaug Riis, 2019

**Discrete Mechanics, Geometric Integration and Lie-Butcher Series** Kurusch Ebrahimi-Fard, María Barbero Liñán, 2018-11-05 This volume resulted from presentations given at the international Brainstorming Workshop on New Developments in Discrete Mechanics Geometric Integration and Lie Butcher Series that took place at the Instituto de Ciencias Matemáticas ICMAT in Madrid Spain It combines overview and research articles on recent and ongoing developments as well as new research directions Why geometric numerical integration In their article of the same title Arieh Iserles and Reinout Quispel two renowned experts in numerical analysis of differential equations provide a compelling answer to this question After this introductory chapter a collection of high quality research articles aim at exploring recent and ongoing developments as well as new research directions in the areas of geometric integration methods for differential equations nonlinear systems interconnections and discrete mechanics One of the highlights is the unfolding of modern algebraic and combinatorial structures common to those topics which give rise to fruitful interactions between theoretical as

well as applied and computational perspectives The volume is aimed at researchers and graduate students interested in theoretical and computational problems in geometric integration theory nonlinear control theory and discrete mechanics

**Geometric Integrators for Differential Equations with Highly Oscillatory Solutions** Xinyuan Wu,Bin

Wang,2021-09-28 The idea of structure preserving algorithms appeared in the 1980 s The new paradigm brought many innovative changes The new paradigm wanted to identify the long time behaviour of the solutions or the existence of conservation laws or some other qualitative feature of the dynamics Another area that has kept growing in importance within Geometric Numerical Integration is the study of highly oscillatory problems problems where the solutions are periodic or quasiperiodic and have to be studied in time intervals that include an extremely large number of periods As is known these equations cannot be solved efficiently using conventional methods A further study of novel geometric integrators has become increasingly important in recent years The objective of this monograph is to explore further geometric integrators for highly oscillatory problems that can be formulated as systems of ordinary and partial differential equations Facing challenging scientific computational problems this book presents some new perspectives of the subject matter based on theoretical derivations and mathematical analysis and provides high performance numerical simulations In order to show the long time numerical behaviour of the simulation all the integrators presented in this monograph have been tested and verified on highly oscillatory systems from a wide range of applications in the field of science and engineering They are more efficient than existing schemes in the literature for differential equations that have highly oscillatory solutions This book is useful to researchers teachers students and engineers who are interested in Geometric Integrators and their long time behaviour analysis for differential equations with highly oscillatory solutions

*Geometric Numerical Integration* Mathematisches Forschungsinstitut Oberwolfach,2006 *Geometric Numerical Integration Applied to the Elastic Pendulum at Higher Order Resonance* Johan Matheus Tuwankotta,G. R. W. Quispel,2000

**Numerical Approximation of Ordinary Differential**

**Problems** Raffaele D'Ambrosio,2023-09-26 This book is focused on the numerical discretization of ordinary differential equations ODEs under several perspectives The attention is first conveyed to providing accurate numerical solutions of deterministic problems Then the presentation moves to a more modern vision of numerical approximation oriented to reproducing qualitative properties of the continuous problem along the discretized dynamics over long times The book finally performs some steps in the direction of stochastic differential equations SDEs with the intention of offering useful tools to generalize the techniques introduced for the numerical approximation of ODEs to the stochastic case as well as of presenting numerical issues natively introduced for SDEs The book is the result of an intense teaching experience as well as of the research carried out in the last decade by the author It is both intended for students and instructors for the students this book is comprehensive and rather self contained for the instructors there is material for one or more monographic courses on ODEs and related topics In this respect the book can be followed in its designed path and includes motivational aspects

historical background examples and a software programs implemented in Matlab that can be useful for the laboratory part of a course on numerical ODEs SDEs The book also contains the portraits of several pioneers in the numerical discretization of differential problems useful to provide a framework to understand their contributes in the presented fields Last but not least rigor joins readability in the book *Discrete Integrable Systems and Geometric Numerical Integration* Shami Ali M.

Alsallami,2018 **Adaptive Geometric Numerical Integration of Mechanical Systems** Klas Modin,Lunds universitet.

Matematikcentrum,2009 **Dynamical Systems: Theoretical and Experimental Analysis** Jan Awrejcewicz,2016-09-17

The book is the second volume of a collection of contributions devoted to analytical numerical and experimental techniques of dynamical systems presented at the international conference Dynamical Systems Theory and Applications held in d Poland on December 7 10 2015 The studies give deep insight into new perspectives in analysis simulation and optimization of dynamical systems emphasizing directions for future research Broadly outlined topics covered include bifurcation and chaos in dynamical systems asymptotic methods in nonlinear dynamics dynamics in life sciences and bioengineering original numerical methods of vibration analysis control in dynamical systems stability of dynamical systems vibrations of lumped and continuous sytems non smooth systems engineering systems and differential equations mathematical approaches to dynamical systems and mechatronics **Symmetries and Integrability of Difference Equations** Decio Levi,Raphaël

Rebelo,Pavel Winternitz,2017-06-30 This book shows how Lie group and integrability techniques originally developed for differential equations have been adapted to the case of difference equations Difference equations are playing an increasingly important role in the natural sciences Indeed many phenomena are inherently discrete and thus naturally described by difference equations More fundamentally in subatomic physics space time may actually be discrete Differential equations would then just be approximations of more basic discrete ones Moreover when using differential equations to analyze continuous processes it is often necessary to resort to numerical methods This always involves a discretization of the differential equations involved thus replacing them by difference ones Each of the nine peer reviewed chapters in this volume serves as a self contained treatment of a topic containing introductory material as well as the latest research results and exercises Each chapter is presented by one or more early career researchers in the specific field of their expertise and in turn written for early career researchers As a survey of the current state of the art this book will serve as a valuable reference and is particularly well suited as an introduction to the field of symmetries and integrability of difference equations Therefore the book will be welcomed by advanced undergraduate and graduate students as well as by more advanced researchers **Geometric Integrators with Application to Hamiltonian Systems** Hebatallah Jamil Sakaji,2015

Geometric numerical integration is a relatively new area of numerical analysis The aim is to preserve the geometric properties of the flow of a differential equation such as symplecticity or reversibility A conventional numerical integrator approximates the flow of the continuous time equations using only the information about the vector field ignoring the

physical laws and the properties of the original trajectory. In this way, small inaccuracies accumulated over long periods of time will significantly diminish the operational lifespan of such discrete solutions. Geometric integrators, on the other hand, are built in a way that preserve the structure of continuous dynamics, so maintaining the qualitative behavior of the exact flow even for long time integration. The aim of this thesis is to design efficient geometric integrators for Hamiltonian systems and to illustrate their effectiveness. These methods are implicit for general non-separable Hamiltonian systems, making them difficult to implement. However, we show that explicit integrators are possible in some cases. Both geometric and non-geometric integration methods are applied to several problems; then we do a comparison between these methods in order to determine which of those quantities are preserved better by these methods. In particular, we develop explicit integrators for a special case of the restricted 3-body problem known as Hill's problem.

**Trends in Contemporary Mathematics** Vincenzo Ancona, Elisabetta Strickland, 2014-08-27. The topics faced in this book cover a large spectrum of current trends in mathematics such as Shimura varieties and the Langlands program, zonotopal combinatorics, non-linear potential theory, variational methods in imaging, Riemann holonomy and algebraic geometry, mathematical problems arising in kinetic theory, Boltzmann systems, Pell's equations in polynomials, deformation theory in non-commutative algebras. This work contains a selection of contributions written by international leading mathematicians who were speakers at the INdAM Day, an initiative born in 2004 to present the most recent developments in contemporary mathematics.

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