

# Some Shadowing Properties in Fuzzy Dynamical System

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**Abstract**—In this paper we introduce the notions (*L-shadowing property*, *two – sided limit shadowing*, *negative limit shadowing property*, *simple two – sided limit shadowing* ) for fuzzy dynamical systems and prove that properties (*fuzzy shadowing property*, *fuzzy L-shadowing property*, *fuzzy two – sided limit shadowing*) are invariant under fuzzy topological conjugation.

**Keywords**— Fuzzy metric space, fuzzy dynamical system, fuzzy *L-shadowing property*, the fuzzy two – sided limit shadowing property, fuzzy negative limit shadowing property , fuzzy *h-shadow*.

## I. INTRODUCTION

Qualitative theory of dynamical systems is the study of the long-term behavior of evolving systems under perturbations ([2])([4]). The evolution of a particular state of a dynamical system is related to its orbits. For this purpose we need to know the structure of these orbits by solving a system of differential equations. If we cannot solve a system of differential equations analytically, then *pseudo orbits* are suggested as replacements for the orbits [4].

The notion *pseudo – orbit tracing property*, also known as *shadowing*, are among the most important concepts in topological dynamics [1]. Also, the rest of the shadowing properties can be studied in the fuzzy dynamic

In this paper we are going to use of fuzzy distances to approximate the pseudo orbits and their shadowing properties [4].

In section 2 we introduce the notions (*fuzzy L – shadowing property*, *fuzzy two – sided limit shadowing*, *fuzzy negative limit shadowing property* ) for fuzzy dynamical system. We prove that these properties (*fuzzy shadowing property*, *fuzzy L-shadowing property*, *fuzzy two – sided limit shadowing*) are invariant under fuzzy topological conjugacy. Also, the rest of the shadowing properties can be studied in the fuzzy dynamical system.

## II. PRELIMINARIES

### Definition 2.1[6]

A binary operation  $\ast : [0, 1] \times [0, 1] \rightarrow [0, 1]$  is called a *continuous triangular norm (t – norm)* if  $\ast$  satisfies the following conditions:

1.  $\ast$  is associative and commutative;
2.  $\ast$  is continuous;
3.  $a \ast 1 = a$  for all  $a \in (0, 1]$ ;
4.  $a \ast b \leq c \ast d$  whenever  $a \leq c$  and  $b \leq d$ ;
5. If  $a \ast b = a \ast c$  then  $b = c$ .

Properties 4 and 5 of a continuous *t – norm* imply that if  $a \ast b \leq a \ast c$  then  $b \leq c$ .

### Definition 2.2[5]

A *fuzzy metric space* is a triple  $(X, M, \ast)$  where  $X$  is a non-empty set,  $\ast$  is a continuous *t – norm* and  $M : X \times X \times (0, \infty) \rightarrow [0, 1]$  is a mapping which has the following properties :

For every  $x, y, z \in X$  and  $t, s > 0$ :

1.  $M(x, y, t) > 0$ ;
2.  $M(x, y, t) = 1$  if and only if  $x = y$ ;
3.  $M(x, y, t) = M(y, x, t)$ ;
4.  $M(x, z, t + s) \geq M(x, y, t) \ast M(y, z, s)$ ;

# Shadowing In Dynamical Systems

**George Osipenko**



## **Shadowing In Dynamical Systems:**

**Shadowing in Dynamical Systems** K.J. Palmer, 2013-03-14 In this book the theory of hyperbolic sets is developed both for diffeomorphisms and flows with an emphasis on shadowing We show that hyperbolic sets are expansive and have the shadowing property Then we use shadowing to prove that hyperbolic sets are robust under perturbation that they have an asymptotic phase property and also that the dynamics near a transversal homoclinic orbit is chaotic It turns out that chaotic dynamical systems arising in practice are not quite hyperbolic However they possess enough hyperbolicity to enable us to use shadowing ideas to give computer assisted proofs that computed orbits of such systems can be shadowed by true orbits for long periods of time that they possess periodic orbits of long periods and that it is really true that they are chaotic

Audience This book is intended primarily for research workers in dynamical systems but could also be used in an advanced graduate course taken by students familiar with calculus in Banach spaces and with the basic existence theory for ordinary differential equations

*Shadowing in Dynamical Systems* Sergei Yu. Pilyugin, 2006-11-14 This book is an introduction to the theory of shadowing of approximate trajectories in dynamical systems by exact ones This is the first book completely devoted to the theory of shadowing It shows the importance of shadowing theory for both the qualitative theory of dynamical systems and the theory of numerical methods Shadowing Methods allow us to estimate differences between exact and approximate solutions on infinite time intervals and to understand the influence of error terms The book is intended for specialists in dynamical systems for researchers and graduate students in the theory of numerical methods

*Shadowing in Dynamical Systems* K. J. Palmer, 2014-01-15 **Shadowing in Dynamical Systems** K.J. Palmer, 2000-02-29 In this book the theory of hyperbolic sets is developed both for diffeomorphisms and flows with an emphasis on shadowing We show that hyperbolic sets are expansive and have the shadowing property Then we use shadowing to prove that hyperbolic sets are robust under perturbation that they have an asymptotic phase property and also that the dynamics near a transversal homoclinic orbit is chaotic It turns out that chaotic dynamical systems arising in practice are not quite hyperbolic However they possess enough hyperbolicity to enable us to use shadowing ideas to give computer assisted proofs that computed orbits of such systems can be shadowed by true orbits for long periods of time that they possess periodic orbits of long periods and that it is really true that they are chaotic Audience This book is intended primarily for research workers in dynamical systems but could also be used in an advanced graduate course taken by students familiar with calculus in Banach spaces and with the basic existence theory for ordinary differential equations

**Shadowing and Hyperbolicity** Sergei Yu Pilyugin, Kazuhiro Sakai, 2017-08-31 Focusing on the theory of shadowing of approximate trajectories pseudotrajectories of dynamical systems this book surveys recent progress in establishing relations between shadowing and such basic notions from the classical theory of structural stability as hyperbolicity and transversality Special attention is given to the study of quantitative shadowing properties such as Lipschitz shadowing it is shown that this property is equivalent to structural

stability both for diffeomorphisms and smooth flows and to the passage to robust shadowing which is also equivalent to structural stability in the case of diffeomorphisms while the situation becomes more complicated in the case of flows. Relations between the shadowing property of diffeomorphisms on their chain transitive sets and the hyperbolicity of such sets are also described. The book will allow young researchers in the field of dynamical systems to gain a better understanding of new ideas in the global qualitative theory. It will also be of interest to specialists in dynamical systems and their applications.

*Handbook of Dynamical Systems* B. Fiedler, 2002-02-21 This handbook is volume II in a series collecting mathematical state of the art surveys in the field of dynamical systems. Much of this field has developed from interactions with other areas of science and this volume shows how concepts of dynamical systems further the understanding of mathematical issues that arise in applications. Although modeling issues are addressed the central theme is the mathematically rigorous investigation of the resulting differential equations and their dynamic behavior. However the authors and editors have made an effort to ensure readability on a non technical level for mathematicians from other fields and for other scientists and engineers. The eighteen surveys collected here do not aspire to encyclopedic completeness but present selected paradigms. The surveys are grouped into those emphasizing finite dimensional methods, numerics, topological methods and partial differential equations. Application areas include the dynamics of neural networks, fluid flows, nonlinear optics and many others. While the survey articles can be read independently they deeply share recurrent themes from dynamical systems: Attractors, bifurcations, center manifolds, dimension reduction, ergodicity, homoclinicity, hyperbolicity, invariant and inertial manifolds, normal forms, recurrence, shift dynamics, stability to name just a few are ubiquitous dynamical concepts throughout the articles.

**Dynamical Systems in Theoretical Perspective** Jan Awrejcewicz, 2018-09-01 This book focuses on theoretical aspects of dynamical systems in the broadest sense. It highlights novel and relevant results on mathematical and numerical problems that can be found in the fields of applied mathematics, physics, mechanics, engineering and the life sciences. The book consists of contributed research chapters addressing a diverse range of problems. The issues discussed include among others: numerical analytical algorithms for nonlinear optimal control problems on a large time interval, gravity waves in a reservoir with an uneven bottom, value distribution and growth of solutions for certain Painlevé equations, optimal control of hybrid systems with sliding modes, a mathematical model of the two types of atrioventricular nodal reentrant tachycardia, non conservative instability of cantilevered nanotubes using the Cell Discretization Method, dynamic analysis of a compliant tensegrity structure for use in a gripper application and Jeffcott rotor bifurcation behavior using various models of hydrodynamic bearings.

**Introduction to Applied Nonlinear Dynamical Systems and Chaos** Stephen Wiggins, 2006-04-18 Mathematics is playing an ever more important role in the physical and biological sciences provoking a blurring of boundaries between scientific disciplines and a resurgence of interest in the modern as well as the classical techniques of applied mathematics. This renewal of interest both in search and teaching has led to the establishment

of the series Texts in Applied Mathematics TAM The development of new courses is a natural consequence of a high level of excitement on the research frontier as newer techniques such as numerical and symbolic computer systems dynamical systems and chaos mix with and reinforce the traditional methods of applied mathematics Thus the purpose of this textbook series is to meet the current and future needs of these advances and to encourage the teaching of new courses TAM will publish textbooks suitable for use in advanced undergraduate and beginning graduate courses and will complement the Applied Mathematical Sciences AMS series which will focus on advanced textbooks and research level monographs Pasadena California J E Marsden Providence Rhode Island L Sirovich College Park Maryland S S Antman Preface to the Second Edition This edition contains a significant amount of new material The main reason for this is that the subject of applied dynamical systems theory has seen explosive growth and expansion throughout the 1990s Consequently a student needs a much larger toolbox today in order to begin research on significant problems

**Discrete and Continuous Dynamical Systems**, 2007

Shadowing and Numerical Analysis of Set-valued Dynamical Systems Janosch Rieger, 2009

**Shadowing Properties of**

**Chaotic Dynamical Systems** Russell H. Murray, 1992

**Dynamical Systems, Graphs, and Algorithms** George

Osipenko, 2006-10-28 This book describes a family of algorithms for studying the global structure of systems By a finite covering of the phase space we construct a directed graph with vertices corresponding to cells of the covering and edges corresponding to admissible transitions The method is used among other things to locate the periodic orbits and the chain recurrent set to construct the attractors and their basins to estimate the entropy and more

Astrophysical and Geophysical Flows as Dynamical Systems Neil J. Balmforth, 1999 Astrophysical and Geophysical Flows as Dynamical Systems was the theme of the 1998 GFD Summer Program With Antonello Provenzale at the helm we sailed headlong into the nonlinear world of astrophysical and geophysical fluid mechanics Simultaneously Charles Tresser gave several energetic presentations surrounding the dynamics of circle maps Unfortunately our third planned speaker John David Crawford fell ill just prior to the program and could not participate Sadly John David passed away later in the summer We will remember him at GFD from the excellent lectures he gave at the cottage during the summer of 1993 In a departure from usual practice and in an effort to lend more coherence to the at times very wide ranging topics discussed at Walsh GFD

*Coevolutionary Computation and Its Applications* Xin Yao, Siang Yew Chong, 2025-04-15 This book introduces the fundamentals of Coevolutionary Computation and presents new methodologies that are developed and then employed for modern real world problem solving in various applications across different domains It is structured in three main parts to support the anticipated general and frequent usage of the book In particular the reader is able to obtain a quick and general introduction on the principles of coevolution in Part I and then go over in detail the specifics how coevolutionary principles are exploited and applied to solve specific problems in the relevant chapters of Parts II and III In this manner Part I will introduce the fundamentals in Coevolutionary Computation with no assumption made on familiarity with Evolutionary Computation literature These

fundamentals include key concepts and operational principles of both evolutionary and coevolutionary processes that are modelled as iterative algorithms and systems implementable in computing machines Parts II and III contain various applications of coevolution to problems that are framed in the context of optimization and learning respectively Detailed procedural implementations are provided for those methodologies as well as analysis that highlight the improvements they bring about over conventional techniques Dynamics of Disc Galaxies Björn Sundelius,1991 1989 Lectures In Complex Systems (volume Ii) Erica Jen,1990-01-21 1989 Lectures in Complex Systems is an important introduction for the emerging field of complex systems Topics covered in the book include problems in computational complexity chaotic behavior and prediction chemical dynamics cellular automata and lattice gases disordered systems parallel processing algorithms morphogenesis and computational and experimental neurobiology The understanding of scientific phenomena derived from traditional approaches is combined with the insights gained from a new view of complexity Emphasis is given to such concepts as order chaos randomness nonlinearity computability collective phenomena and emergent structures The volume is a comprehensive treatise that presents the work of researchers whose study of specific problems in mathematics physics chemistry biology and computer science is interlaced throughout by curiosity about the nature and mechanisms of complex behavior This proceedings volume is based on the 1989 Complex Systems Summer School at St John s College in Santa Fe New Mexico It complements subjects covered in Lectures in the Sciences of Complexity Addison Wesley 1989 edited by Daniel L Stern and based on the 1988 Complex Systems Summer School *Nonlinear Dynamics and the Spatiotemporal Principles of Biology* Friedrich Beck (fizyka jądrowa),2003 *Fundamenta Mathematicae* ,2016 **Topological and Symbolic Dynamics** Petr Kůrka,2003 A dynamical system is a continuous self map of a compact metric space Topological dynamics studies the iterations of such a map or equivalently the trajectories of points of the state space The basic concepts of topological dynamics are minimality transitivity recurrence shadowing property stability equicontinuity sensitivity attractors and topological entropy Symbolic dynamics studies dynamical systems whose state spaces are zero dimensional and consist of sequences of symbols The main classes of symbolic dynamical systems are adding machines subshifts of finite type sofic subshifts Sturmian substitutive and Toeplitz subshifts and cellular automata *Morphogenesis, Tectonic Setting and Intrusion Dynamics of the Late-Variscan Granites at the Northwest-margin of the Bohemian Massif* Robert Trzebski,1997

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