Pattern formation in annular systems of repulsive particles
General particle models with symmetric and asymmetric repulsion are studied and investigated for finite-range and exponential interaction in an annulus. In the symmetric case transitions from one- to multi-lane behavior including multistability are observed for varying particle density and for a varying curvature with fixed density. Hence, the system cannot be approximated by a periodic channel. In the asymmetric case, which is important in pedestrian dynamics, we reveal an inhomogeneous new phase, a traveling wave reminiscent of peristaltic motion.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Physics, Bogolyubov Institute for Theoretical Physics
Authors: Marschler, C. (Intern), Starke, J. (Intern), Sørensen, M. P. (Intern), Gaididei, Y. B. (Ekstern), Christiansen, P. L. (Intern)
Pages: 166-170
Publication date: 2016
Main Research Area: Technical/natural sciences

Publication information
Volume: 380
Issue number: 1-2
ISSN (Print): 0375-9601
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.69 SJR 0.683 SNIP 1.064
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.713 SNIP 1.159 CiteScore 1.74
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.699 SNIP 1.024 CiteScore 1.71
Web of Science (2014): Indexed yes


Bifurcation of learning and structure formation in neuronal maps

Most learning processes in neuronal networks happen on a much longer time scale than that of the underlying neuronal dynamics. It is therefore useful to analyze slowly varying macroscopic order parameters to explore a network’s learning ability. We study the synaptic learning process giving rise to map formation in the laminar nucleus of the barn owl’s auditory system. Using equation-free methods, we perform a bifurcation analysis of spatio-temporal structure formation in the associated synaptic-weight matrix. This enables us to analyze learning as a bifurcation process and follow the unstable states as well. A simple time translation of the learning window function shifts the bifurcation point of structure formation and goes along with traveling waves in the map, without changing the animal's sound localization performance.

General information
State: Published
Coarse Analysis of Microscopic Models using Equation-Free Methods

Mathematical models of real-world problems from physics, biology and chemistry have become very complex over the last three decades. Although increasing computational power allows to solve even larger systems of differential equations, the number of differential equations is still a main limiting factor for the complexity of models, e.g., in real-time applications. With the increasing amount of data generated by computer simulations a challenge is to extract valuable information from the models in order to help scientists and managers in a decision-making process. Although the dynamics of these models might be high-dimensional, the properties of interest are usually macroscopic and low-dimensional in nature. Examples are numerous and not necessarily restricted to computer models. For instance, the power output, energy consumption and temperature of engines are interesting quantities for engineers, although the models they base their design on are described for the gas mixture (a system with many degrees-of-freedom) inside a combustion engine. Since good models are often not available on the macroscopic scale the necessary information has to be extracted from the microscopic, high-dimensional models.

The goal of this thesis is to investigate such high-dimensional multiscale models and extract relevant low-dimensional information from them. Recently developed mathematical tools allow to reach this goal: a combination of so-called equation-free methods with numerical bifurcation analysis is used and further developed to gain insight into high-dimensional systems on a macroscopic level of interest. Based on a switching-procedure between a detailed microscopic and a coarse macroscopic level during simulations it is possible to obtain a closure-on-demand for the macroscopic dynamics by only using short simulation bursts of computationally-expensive complex models. Those information is subsequently used to construct bifurcation diagrams that show the parameter dependence of solutions of the system.

The methods developed for this thesis have been applied to a wide range of relevant problems. Applications include the learning behavior in the barn owl’s auditory system, traffic jam formation in an optimal velocity model for circular car traffic and oscillating behavior of pedestrian groups in a counter-flow through a corridor with narrow door. The methods do not only quantify interesting properties in these models (learning outcome, traffic jam density, oscillation period), but also allow to investigate unstable solutions, which are important information to determine basins of attraction of stable solutions and thereby reveal information on the long-term behavior of an initial state.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Marschler, C. (Intern), Starke, J. (Intern)
Number of pages: 189
Publication date: 2014

Publication information
Place of publication: Kgs. Lyngby
Publisher: Technical University of Denmark (DTU)
Original language: English

Series: DTU Compute PHD-2014
Number: 342
ISSN: 0909-3192
Main Research Area: Technical/natural sciences
Electronic versions:
phd342_Marschler_C.pdf
Publication: Research › Ph.D. thesis – Annual report year: 2014
Coarse-grained particle model for pedestrian flow using diffusion maps

Interacting particle systems constitute the dynamic model of choice in a variety of application areas. A prominent example is pedestrian dynamics, where good design of escape routes for large buildings and public areas can improve evacuation in emergency situations, avoiding exit blocking and the ensuing panic. Here we employ diffusion maps to study the coarse-grained dynamics of two pedestrian crowds trying to pass through a door from opposite sides. These macroscopic variables and the associated smooth embeddings lead to a better description and a clearer understanding of the nature of the transition to oscillatory dynamics. We also compare the results to those obtained through intuitively chosen macroscopic variables.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Princeton University
Authors: Marschler, C. (Intern), Starke, J. (Intern), Liu, P. (Ekstern), Kevrekidis, I. G. (Ekstern)
Number of pages: 11
Publication date: 2014
Main Research Area: Technical/natural sciences

Publication information
Volume: 89
Issue number: 1
Article number: 013304
ISSN (Print): 1539-3755
Ratings:
Web of Science (2018): Indexed yes
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.95 SJR 0.993 SNIP 0.896
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.047 SNIP 0.978 CiteScore 1.89
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.22 SNIP 1.123 CiteScore 2.05
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.311 SNIP 1.239 CiteScore 2.28
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.42 SNIP 1.226 CiteScore 2.28
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.485 SNIP 1.225 CiteScore 2.28
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.69 SNIP 1.215
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.694 SNIP 1.259
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 1.96 SNIP 1.314
Web of Science (2008): Indexed yes
Equation-Free Analysis of Macroscopic Behavior in Traffic and Pedestrian Flow

Equation-free methods make possible an analysis of the evolution of a few coarse-grained or macroscopic quantities for a detailed and realistic model with a large number of fine-grained or microscopic variables, even though no equations are explicitly given on the macroscopic level. This will facilitate a study of how the model behavior depends on parameter values including an understanding of transitions between different types of qualitative behavior. These methods are introduced and explained for traffic jam formation and emergence of oscillatory pedestrian counter flow in a corridor with a narrow door.

Implicit methods for equation-free analysis: convergence results and analysis of emergent waves in microscopic traffic models

We introduce a general formulation for an implicit equation-free method in the setting of slow-fast systems. First, we give a rigorous convergence result for equation-free analysis showing that the implicitly defined coarse-level time stepper converges to the true dynamics on the slow manifold within an error that is exponentially small with respect to the small parameter measuring time scale separation. Second, we apply this result to the idealized traffic modeling problem of phantom jams generated by cars with uniform behavior on a circular road. The traffic jams are waves that travel slowly
against the direction of traffic. Equation-free analysis enables us to investigate the behavior of the microscopic traffic model on a macroscopic level. The standard deviation of cars' headways is chosen as the macroscopic measure of the underlying dynamics such that traveling wave solutions correspond to equilibria on the macroscopic level in the equation-free setup. The collapse of the traffic jam to the free flow then corresponds to a saddle-node bifurcation of this macroscopic equilibrium. We continue this bifurcation in two parameters using equation-free analysis.

**General information**

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, University of Exeter, AKAD University of Applied Sciences, Toyota Central Research & Development Laboratories, Inc.
Authors: Marschler, C. (Intern), Sieber, J. (Ekstern), Berkemer, R. (Intern), Kawamoto, A. (Intern), Starke, J. (Intern)
Pages: 1202-1238
Publication date: 2014
Main Research Area: Technical/natural sciences

**Publication information**

Journal: S I A M Journal on Applied Dynamical Systems
Volume: 13
Issue number: 3
ISSN (Print): 1536-0040
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 1.88 SJR 1.256 SNIP 1.297
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.358 SNIP 1.389 CiteScore 1.89
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.167 SNIP 1.217 CiteScore 1.67
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.306 SNIP 1.34 CiteScore 1.85
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.221 SNIP 1.486 CiteScore 1.77
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.494 SNIP 1.41 CiteScore 1.91
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.204 SNIP 1.187
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.299 SNIP 1.613
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.276 SNIP 1.508
Scopus rating (2007): SJR 1.55 SNIP 1.472
Scopus rating (2006): SJR 1.781 SNIP 1.465
Scopus rating (2005): SJR 1.227 SNIP 1.899
Scopus rating (2004): SJR 1.107 SNIP 2.233
Scopus rating (2003): SJR 0.536 SNIP 0.702
Original language: English
DOIs:
Nonlinear Effects in Examples of Crowd Evacuation Scenarios

Severe accidents with many fatalities have occurred when too many pedestrians had to maneuver in too tight surroundings, as during evacuations of mass events. This demonstrates the importance of a better general understanding of pedestrians and emergent complex behavior in crowds. To this end, we develop both a new microscopic agent-based pedestrian model and also study simplified evacuation scenarios which permit the isolation of relevant nonlinear effects and their systematic investigation. We concentrate on two effects: First, the influence of the position and size of an obstacle in front of an emergency exit on the flux through the exit, and second, the influence of other pedestrians on the route choice of an individual. The first investigation demonstrates the possibility of improving substantially the flow through an exit by placing an obstacle in a suitable way in front of it. The latter shows clearly bistable states and hysteresis effects, indicating the existence of unstable pedestrian flow states in addition to the stable states. Furthermore, this set-up is an example of a radical change of the pedestrian flux by only a small change in the geometry of the evacuation scenario. The results motivate further investigation and eventually engineering use by optimizing the design of large buildings, stations, airports and stadiums for mass events.

Unidirectionally Coupled Map Lattices with Nonlinear Coupling: Unbinding Transitions and Superlong Transients

Recently, highly resolved experiments and simulations have provided detailed insight into the dynamics of turbulent pipe flow. This has revived the interest in identifying mechanisms that generate chaotic transients with superexponential growth of lifetime as a function of a control parameter, the Reynolds number for pipe flow, and with transitions from bounded chaotic patches to an invasion of space of irregular motion. Dynamical systems models are unique tools in this respect because they can provide insight into the origin of the very long lifetime of puffs, and the dynamical mechanism leading to the transition from puffs to slugs in pipe flow. The present paper contributes to this enterprise by introducing a unidirectionally coupled map lattice. It mimics three of the salient features of pipe-flow turbulence: (i) the transition from laminar flow to puffs, (ii) a superexponential scaling of puff lifetime, and (iii) the transition from puffs to slugs by an unbinding transition in an intermittency scenario. In our model all transitions and scalings are theoretically described from a dynamical systems point of view.
**Projects:**

**Analysis of Pattern Formation on Networks**

Technical University of Denmark  
Period: 01/08/2011 → 21/11/2014  
Number of participants: 5  
Phd Student: Marschler, Christian (Intern)  
Main Supervisor: Starke, Jens (Intern)
Examiner:
Christiansen, Lasse Engbo (Intern)
Barkley, Dwight (Ekstern)
Sugiyama, Yuki (Ekstern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU) Samf.
Project: PhD