Nikolay Pogodaev

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Personal

Born	November 7, 1982
Citizenship	Israel • Russia
Marital status	Married, one son

Education

Institute for System Dynamics and Control Theory — Irkutsk, Russia

PhD in Mathematics — 2009

Irkutsk State University — Irkutsk, Russia

Specialist Degree in Mathematics — 2005

Employment

Università degli studi di Padova — Padova, Italy

Researcher (tempo determinato) — 2022-today

Institute for System Dynamics and Control Theory — Irkutsk, Russia

Senior researcher — 2018-2022

Researcher — 2012-2018

Università degli studi di Brescia — Brescia, Italy

Postdoctoral researcher — 2011-2012

Institute for System Dynamics and Control Theory — Irkutsk, Russia

Junior researcher — 2009-2011

Languages

Natural	Russan (native), English (fluent), French (intermediate), Italian (intermediate)
Programming	C/C++, Python, Julia

Research interests

My primary research interest is mathematical control theory, especially, when it deals with PDEs and mingles with optimal transportation. Doing my Ph.D. made me appreciate set-valued analysis and my postdoc research gave me a taste of geometric measure theory and nonlinear conservation laws. When I'm getting tired of proving theorems, I do some programming for tackling optimal control problems by numerical tools.

Publications

⋆ marks the most important papers

Preprints

[3] R. Chertovskih, N. Pogodaev, M. Staritsyn, J. D. S. Sewane, and A. P. Aguiar. *Optimization of external stimuli for populations of theta neurons via mean-field feedback control*. Jan. 2023.

Journal Articles

[1⋆] R. Chertovskih, N. Pogodaev, and M. Staritsyn. "Optimal Control of Nonlocal Continuity Equations: Numerical Solution". In: *Applied Mathematics & Optimization* 88.3 (Oct. 2023), p. 86. DOI: 10.1007/s00245-023-10062-w.

[2] R. Chertovskih, N. Pogodaev, M. Staritsyn, and A. P. Aguiar. "Optimal Control of Distributed Ensembles With Application to Bloch Equations". In: *IEEE Control Systems Letters* 7 (2023), pp. 2059–2064. DOI: 10.1109/LCSYS.2023.3284205.

[4] R. Chertovskih, F. L. Pereira, N. Pogodaev, and M. Staritsyn. "Optimization in a traffic flow model as an inverse problem in the Wasserstein space". en. In: *IFAC-PapersOnLine* 55.16 (2022), pp. 32–37. DOI: 10.1016/j.ifacol.2022.08.077.

[5⋆] N. I. Pogodaev and M. V. Staritsyn. "Nonlocal balance equations with parameters in the space of signed measures". en. In: *Sbornik: Mathematics* 213.1 (2022). DOI: 10.1070/SM9516.

[6⋆] M. Staritsyn, N. Pogodaev, R. Chertovskih, and F. Lobo Pereira. "Feedback maximum principle for ensemble control of local continuity equations: an application to supervised machine learning". In: *IEEE Control Systems Letters* 6 (2022), pp. 1046–1051. DOI: 10.1109/lcsys.2021.3089139.

[7] M. Staritsyn, N. Pogodaev, and F. L. Pereira. "Linear-quadratic problems of optimal control in the space of probabilities". In: *IEEE Control Systems Letters* 6 (2022), pp. 3271–3276. DOI: 10.1109/lcsys.2022.3184257.

[8] N. S. Maltugueva, N. I. Pogodaev, and O. N. Samsonyuk. "Optimization of impulsive control systems with intermediate state constraints". In: *Izvestiya Irkutskogo Gosudarstvennogo Universiteta. Seriya Matematika* 35 (2021), pp. 18–33. DOI: 10.26516/1997-7670.2021.35.18.

[9⋆] N. Maltugueva and N. Pogodaev. "Modeling of crowds in regions with moving obstacles". In: *Discrete and Continuous Dynamical Systems. Series A* 41.11 (2021), pp. 5009–5036. DOI: 10.3934/dcds.2021066.

[11⋆] N. Pogodaev and M. Staritsyn. "Impulsive control of nonlocal transport equations". In: *Journal of Differential Equations* 269.4 (2020), pp. 3585–3623. DOI: 10.1016/j.jde.2020.03.007.

[13] N. I. Pogodaev. “Bang-bang theorem for a coupled ODE-PDE control system”. In: *Journal of Mathematical Sciences (New York)* 239.2, Problems in mathematical analysis. No. 96 (2019), pp. 146–158. DOI: 10.1007/s10958-019-04298-7.

[14] N. Pogodaev. “Program strategies for a dynamic game in the space of measures”. In: *Optimization Letters* 13.8 (2019), pp. 1913–1925. DOI: 10.1007/s11590-018-1318-y.

[15] M. V. Staritsyn and N. I. Pogodaev. “On a class of optimal impulse control problems for a continuity equation”. Russian. In: *Trudy Instituta Matematiki i Mekhaniki* 25.1 (2019), pp. 229–244. DOI: 10.21538/0134-4889-2019-25-1-229-244.

[17⋆] N. Pogodaev. “Estimates of the domain of dependence for scalar conservation laws”. In: *Journal of Differential Equations* 265.4 (2018), pp. 1654–1677. DOI: 10.1016/j.jde.2018.04.015.

[18] N. I. Pogodaev and V. A. Voronov. “Minimum time function of a non-autonomous control system”. en. In: *IFAC-PapersOnLine* 51.32 (2018), pp. 704–707. DOI: 10.1016/j.ifacol.2018.11.508.

[19] M. V. Staritsyn, N. S. Maltugueva, N. I. Pogodaev, and S. P. Sorokin. “Impulsive control of systems with network structure that describe processes for the spread of political influence”. Russian. In: *Izvestiya Irkutskogo Gosudarstvennogo Universiteta. Seriya Matematika* 25 (2018), pp. 126–143. DOI: 10.26516/1997-7670.2018.25.126.

[20] M. V. Staritsyn and N. I. Pogodaev. “On a Class of Impulsive Control Problems for Continuity Equations”. en. In: *IFAC-PapersOnLine* 51.32 (2018), pp. 468–473. DOI: 10.1016/j.ifacol.2018.11.429.

[21] N. S. Maltugueva and N. I. Pogodaev. “On the existence of a solution to an optimal control problem for a hybrid system”. Russian. In: *Izvestiya Irkutskogo Gosudarstvennogo Universiteta. Seriya Matematika* 19 (2017), pp. 129–135. DOI: 10.26516/1997-7670.2017.19.129.

[23] N. I. Pogodaev. “On the regularity of the boundary of the integral funnel of a differential inclusion”. In: *Differential Equations* 52.8 (2016), pp. 987–999. DOI: 10.1134/S0012266116080048.

[24⋆] N. Pogodaev. “Optimal control of continuity equations”. In: *NoDEA. Nonlinear Differential Equations and Applications* 23.2 (2016), Art. 21, 24. DOI: 10.1007/s00030-016-0357-2.

[25] R. M. Colombo, T. Lorenz, and N. I. Pogodaev. “On the modeling of moving populations through set evolution equations”. In: *Discrete and Continuous Dynamical Systems. Series A* 35.1 (2015), pp. 73–98. DOI: 10.3934/dcds.2015.35.73.

[27⋆] N. I. Pogodaev and A. A. Tolstonogov. “Variational stability of an optimal control problem for a Volterra-type equation”. In: *Siberian Mathematical Journal* 55.4 (2014), pp. 818–839. DOI: 10.1134/s0037446614040090.

[28] R. M. Colombo and N. Pogodaev. “On the control of moving sets: positive and negative confinement results”. In: *Siam Journal On Control and Optimization* 51.1 (2013), pp. 380–401. DOI: 10.1137/12087791X.

[29⋆] R. M. Colombo and N. Pogodaev. “Confinement strategies in a model for the interaction between individuals and a continuum”. In: *Siam Journal On Applied Dynamical Systems* 11.2 (2012), pp. 741–770. DOI: 10.1137/110854321.

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[33] N. I. Pogodaev. "On solutions of the Goursat-Darboux system with boundary and distributed controls". In: *Differential Equations* 43.8 (2007), pp. 1142–1152. DOI: 10.1134/S0012266107080125.

[34] N. I. Pogodaev. "On the properties of solutions of the Goursat-Darboux problem with boundary and distributed controls". In: *Sibirsk. Mat. Zh.* 48.5 (2007), pp. 1116–1133. DOI: 10.1007/s11202-007-0092-3.

Conference Proceedings

[10] M. Staritsyn, N. Pogodaev, and E. Goncharova. "Feedback maximum principle for a class of linear continuity equations inspired by optimal impulsive control". In: *Mathematical optimization theory and operations research*. Vol. 12755. Lecture notes in comput. Sci. Springer, Cham, 2021, pp. 356–368. DOI: 10.1007/978-3-030-77876-7_24.

[12] N. Maltugueva, N. Pogodaev, and O. Samsonyuk. "Optimality conditions and numerical algorithms for hybrid control systems". In: *Mathematical optimization theory and operations research*. Vol. 11548. Lecture notes in comput. Sci. Springer, Cham, 2019, pp. 474–488. DOI: 10.1007/978-3-030-22629-9_33.

[16] M. Staritsyn and N. Pogodaev. "Impulsive relaxation of continuity equations and modeling of colliding ensembles". In: *Optimization and applications*. Vol. 974. Commun. Comput. Inf. Sci. Springer, Cham, 2019, pp. 367–381. DOI: 10.1007/978-3-030-10934-9_26.

[22] N. Pogodaev. "Numerical Algorithm for Optimal Control of Continuity Equations". In: *Proc. of 8th Intern. Conf. on Optimization and Applications, OPTIMA-2017*. Vol. 1987. CEUR Workshop Proceedings. 2017, pp. 467–474.

[26] R. M. Colombo, M. Garavello, M. Lécureux-Mercier, and N. Pogodaev. "Conservation laws in the modeling of moving crowds". In: *Hyperbolic problems: theory, numerics, applications*. Vol. 8. AIMS ser. Appl. Math. Am. Inst. Math. Sci. (AIMS), Springfield, MO, 2014, pp. 467–474.

Conferences and seminars

⋆ marks plenary talks

2023 Conference on Control, Decision and Information Technologies (Rome, Italy)

2023 Seminar at University of Porto (Porto, Portugal)

2022 Conference on Mean field games, mean field type control theory and applications (Sochi, Russia)

2022 18th IFAC Workshop on Control Applications of Optimization (Gif sur Yvette, France)

2022 6th School-Seminar on Nonlinear Analysis and Extremal Problems (Irkutsk, Russia)

2019 Conference "Crowds: models and control" (Marseille, France)

⋆ 2019 Youth School-Conference "Modern problems in mathematics and its applications" (Yekaterinburg, Russia)

2018 17th IFAC Workshop on Control Applications of Optimization (Yekaterinburg, Russia)

2018 14th Viennese Conference "Optimal Control and Dynamic Games" (Vienna, Austria)

- 2018 9th Conference on Optimization and Applications (Petrovac, Montenegro)
- 2018 6th School-Seminar on Nonlinear Analysis and Extremal Problems (Irkutsk, Russia)
- ⋆ 2017 Conference on Mathematical Control Theory and Mechanics (Suzdal, Russia)
- 2017 8th Conference on Optimization and Applications (Petrovac, Montenegro)
- 2016 Conference on Geometric Analysis and Control Theory (Novosibirsk, Russia)
- 2016 5th School-Seminar on Nonlinear Analysis and Extremal Problems (Irkutsk, Russii)
- 2015 Conference "Kolmogorov Readings, General Control Problems and Their Applications" (Tambov, Russia)
- 2015 3rd Conference for Young Scientists on Mathematical Modeling, Computing Technologies and Control (Irkutsk, Russia – Khankh, Mongolia)
- 2014 Symposium "Generalized Statements and Solutions of Control Problems" (Gelendzhik, Russia)
- 2014 4rd School-Seminar on Nonlinear Analysis and Extremal Problems (Irkutsk, Russia)
- 2013 Conference "Mathematical Control in Trieste" (Trieste, Italy)
- 2013 Conference "Kolmogorov Readings, General Control Problems and Their Applications" (Tambov, Russia)
- 2013 2rd Conference for Young Scientists on Mathematical Modeling, Computing Technologies and Control (Irkutsk, Russia – Khankh, Mongolia)
- 2013 Seminar at Università Cattolica del Sacro Cuore (Brescia, Italy)
- 2012 3rd School-Seminar on Nonlinear Analysis and Extremal Problems (Irkutsk, Russia)
- 2012 Seminar at Università degli Studi di Brescia (Brescia, Italy)
- 2012 Seminar at Università degli Studi di Padova (Padova, Italy)
- 2011 Conference on Differential Equations and Related Topics (Moscow, Russia)
- 2009 Conference "Kolmogorov Readings, General Control Problems and Their Applications" (Tambov, Russia)
- 2008 1st School-Seminar on Nonlinear Analysis and Extremal Problems (Irkutsk, Russia)
- 2008 Conference on Differential Equations and Topology (Moscow, Russia)
- 2007 Conference on Differential equations, Theory of Functions and Applications (Novosibirsk, Russia)
- 2007 Conference on Analytical Mechanics, Stability and Motion Control (Irkutsk, Russia)
- 2006 Conference on Control Theory and Mathematical Modeling (Izhevsk, Russia)

Conference organization

⋆ marks conferences where I was the secretary of the organizing committee

I participated in organization of several conferences held in Irkutsk. Among them:

- School-Seminar on Nonlinear Analysis and Extremal Problems (2008, 2010, 2014, 2016, 2018⋆, 2022⋆)
- Mathematical Optimization Theory and Operations Research (2021)
- Conference for Young Scientists on Mathematical Modeling, Computing Technologies and Control (2013, 2015)

Grants

2018-2021	Russian Foundation for Basic Research No. 18-01-00026-a	participant
2018-2019	Russian Foundation for Basic Research No. 18-31-00425-mol_a	participant
2017-2021	Russian Science Foundation No. 17-11-01093	co-investigator
2017-2019	Russian Foundation for Basic Research No. 17-01-00733-a	participant
2016-2017	Russian Foundation for Basic Research No. 16-31-00184-mol_a	participant
2014-2015	Russian Foundation for Basic Research No. 14-01-31254-mol_a	leader

Teaching activity

2017	Exercises for the Bachelor course Convex programming	Irkutsk State University
2016-2019	Exercises for the Bachelor course Linear programming	Irkutsk State University
2016	Lectures for the Bachelor course Linear programming	Irkutsk State University
2015	Lectures for the Bachelor course Optimization	Irkutsk State University

Referee activity

I write referee reports for the following journals:

- Journal of Optimization Theory and Applications
- SIAM Journal on Control and Optimization
- Discrete and Continuous Dynamical Systems
- International Journal of Control
- Topological Methods in Nonlinear Analysis
- Set-Valued and Variational Analysis
- Mathematical Notes

Overview of my research

Nonlinear Volterra operator equations

The articles [27⋆, 30, 32–34] are related to my PhD thesis. They deal with nonlinear Volterra operator equations, a class of operator equations that provide a convenient framework for studying initial-boundary value problems for various PDEs: Goursat-Darboux systems, first-order semilinear hyperbolic systems, the nonlinear wave equation, etc. First, I studied various topological properties of the solution set of the Goursat-Darboux control system [32–34], then proved a Bogolyubov-type relaxation theorem [30]. In our joint paper with A.A. Tolstonogov [27⋆], we proved that optimal control problems for a general nonlinear Volterra equation are stable (in the sense of Γ-convergence) under a wide range of perturbations.

Agent-population interaction via set evolution equations

Together with R.M. Colombo, we studied control problems in some models of agent-population interaction. We started from a model based on differential inclusions and focused on the confinement problem: finding agents' strategies that keep the population inside a given set within a given period of time. We found confinement strategies under certain conditions related to the diameter of the set initially occupied by the population [29⋆]. We proved that there is no confinement strategy if the area of the initial set is sufficiently large [28]. Finally, we generalized the model by developing the concept of a set evolution equation [25].

Control of continuity equations: analytical results

Another set of papers addresses the problem of controlling continuity equations. In [24⋆], Pontryagin's maximum principle was derived for the case of a linear continuity equation. Then, in [22], it was used to construct a descent numerical method for solving the corresponding optimal control problem. A nonlocal continuity equation was considered in [11⋆]. Since unbounded controls were admitted, we constructed an impulsive relaxation of the optimal control problem and derived a necessary optimality condition. Paper [17⋆] can be considered as a bridge between models based on conservation laws and differential inclusions. It shows that the domain of dependence of a nonlinear scalar conservation law lies in the reachable set of a certain differential inclusion. A novel model of crowd motion in regions with moving obstacles is presented in [9⋆] we prove its well-posedness and discuss some applications to environmental optimization.

Recently, in collaboration with Francesco Rossi, we began to study the controllability of nonlocal continuity equations. When the control, represented by a bounded Lipschitz vector field, acts over the entire space, the question is settled: the equation is approximately controllable in the space of absolutely continuous measures. However, when the control is localized (acting only on a bounded set), the situation becomes more complex. A preprint on this topic will soon appear.

Optimal control of continuity equations: numerical algorithms

The most recent papers [1⋆–4⋆, 6⋆, 7, 10] are devoted to the numerical analysis of optimal control problems for nonlocal continuity equations. In these papers we tried to bridge the gap between theory and practice that exists in the field.

The known version of PMP has never been used before to construct numerical algorithms in the nonlocal case due to the following fact: for employing PMP, one must solve an inverse Cauchy problem for a specific Hamiltonian system (basically, a nonlocal continuity equation on a cotangent bundle to the agents' state space); but the terminal condition for this system is concentrated on a subset of the cotangent bundle having zero Lebesgue measure. This means that one cannot transition to density functions and use standard numerical methods to solve the Hamiltonian system. Recently, in a joint work with Maxim Staritsyn and Roman Chertovskikh [1⋆], we were able to bypass this difficulty and construct a working PMP-based optimization algorithm, which converges in the sense that it reduces a certain "measure of non-extremality" of controls.

Another approach [6⋆, 7, 10], developed now only for linear continuity equations (those that contain no nonlocal terms), is based on the so-called exact increment formula, which has little to do with first-order optimality conditions but rather resembles the Hilbert integral in the classical calculus of variations. The corresponding descent algorithm, in contrast to the one based on PMP, does not require any line search. However, this advantage is not for free: computing the first-order increment requires integrating a *linear* transport equation, while computing the exact increment requires solving a *nonlocal* transport equation.