

Curriculum Vitae of Alexey Mashtakov

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Personal Data

Born: May 29, 1987, in Serpukhov, USSR.

Citizenship: Russia.

Address: 52/7, Komsomolskiy lane, 140170, Bronnicy, Russia.

E-mail: alexey.mashtakov@gmail.com

Education: Post-doctoral fellow, TU/e (Eindhoven University of Technology), Eindhoven, The Netherlands, September - October, 2018 (supervisor Prof. Remco Duits)

Secondment, UNIBO (Alma Mater Studiorum Universita di Bologna), Bologna, Italy, January - April, 2016 (supervisor Prof. Giovanna Citti)

Post-doctoral fellow, TU/e (Eindhoven University of Technology), Eindhoven, The Netherlands, 2014–2016 (supervisors Prof. Remco Duits and Prof. Bart ter Haar Romeny)

Ph.D. in Applied Mathematics and Computer Science, Ailamazyan Program Systems Institute of Russian Academy of Sciences, 2012 (supervisor: Yu.L. Sachkov)

M.S. in Applied Mathematics and Computer Science, University of Pereslavl, 2009 (Supervisor: Yu.L. Sachkov).

Foreign Languages: English.

Positions: Senior researcher, Control Process Research Centre of Ailamazyan Program Systems Institute of Russian Academy of Sciences (PSI RAS), since 2015.

Assistant professor, Department of Mathematics, University of Pereslavl, 2016–2017.

Junior researcher, Control Process Research Centre of PSI RAS, 2012–2014.

Research engineer, Control Process Research Centre of PSI RAS, 2010–2012.

Engineer, Control Process Research Centre of PSI RAS, 2006–2010.

Research Interests: Sub-Riemannian Geometry, Invariant Control Systems on Lie Groups, Optimal Control, Nonlinear Geometric Control Theory, Motion Planning, Applications to Robotics, Mechanics, Image Processing and Modelling of Human Visual System.

Languages/Programming: Wolfram Mathematica, C/C++.

Grants

Research grants from Russian Science Foundation (since 2017).
Research grants from RFBR and Russian Government (2006-2021).
EU-Marie Curie (FP7-PEOPLE-2013-ITN, Grant Agreement No. 607643), 2014.
SADCO (FP7-PEOPLE-ITN-2010, Grant Agreement No. 264735), 2012.

Reviewer

Applied Numerical Mathematics, since 2024.
Siberian Electronic Mathematical Reports, since 2024.
Biomimetics, since 2023.
Proceedings of the Steklov Institute of Mathematics, since 2022.
Regular and Chaotic Dynamics, since 2021.
Russian Journal of Nonlinear Dynamics, since 2021.
Journal of Imaging, since 2021.
Mathematics, since 2021.
Applied Mathematics and Computation, since 2020.
Mathematical and Computational Applications, since 2020.
IEEE Access, since 2019.
Contributions to Algebra and Geometry, since 2018.
Journal of Mathematical Imaging and Vision, since 2017.
Sbornik: Mathematics, since 2017.
American Control Conference, since 2016.
Journal of Dynamical and Control Systems, since 2015.
Publicationes Mathematicae Debrecen, since 2015.
Automation and Remote Control, since 2012.

Awards/Achievements

Diploma in the category “Outstanding report”, *The third traditional youth summer school “Control, Information and Optimization”*, Yaropolec, Russia, 2011.
Certificate for the best report, *International student, postgraduate and young scientist conference “Lomonosov-2011”*, Moscow, Russia, 2011.

Teaching Experience

Lecturer: Training modules “Modern methods of information theory, optimization and control”, Sirius University of Science and Technology, 2020-2021.

Teaching assistant: Additional chapters of Calculus, University of Pereslavl, 2016.

Tutor: Calculus B, Eindhoven University of Technology, 2015.

Lecturer: Algebra, University of Pereslavl, 2012.

Teaching assistant: Practical training session on computer (work in Wolfram Mathematica), University of Pereslavl, 2011.

Teaching assistant: Practical training session on computer (a supplement to the course of PDE's), University of Pereslavl, 2011.

Teaching assistant: Ordinary differential equations, University of Pereslavl, 2010.

Publications

Papers in Reviewed Journals

1. (with Yu. Sachkov, A. Ardentov, V. Kasimov) Reconstruction of images via variational principle (in Russian), *Programmnyye produkty i sistemy*, No. 4, 126–127, 2009.
2. (with Yu. Sachkov) Extremal trajectories and the asymptotics of the Maxwell time in the problem of the optimal rolling of a sphere on a plane, *Sbornik Mathematics*, 202:9, 1–25, 2011.
3. Parallel software package for nonholonomic control problems (in Russian), *Programmnyye produkty i sistem*, No. 1, 146–151, 2012.
4. Algorithms and Software Solving a Motion Planning Problem for Nonholonomic Five-dimensional Control Systems (in Russian), *Program Systems: Theory and Applications*, 3–29, 2012.
5. (with A. Ardentov, I. Beschastny, Y. Sachkov, A. Popov, E. Sachkova) Algorithms for evaluation position and orientation of UAV (in Russian), *Programmnyye Sistemy: Teoriya i Prilozheniya*, No. 3, 23–29, 2012.
6. (with Yu. Sachkov, A. Ardentov) Parallel Algorithm and Software for Image Inpainting via Sub-Riemannian Minimizers on the Group of Rototranslations, *Numerical Mathematics: Theory, Methods and Applications (NM-TMA)*, 6:1, 61–95, 2013.
7. (with A. Popov) Asymptotics of Maxwell time in the plate-ball problem, *Journal of Mathematical Sciences*, 195:3, 336–368, 2013.
8. Asymptotics of Extremal Curves in the Ball Rolling Problem on the Plane, *Journal of Mathematical Sciences*, 199:6, 687–694, 2014.
9. (with Y. Sachkov) Integrability of left-invariant sub-Riemannian structures on the special linear group $SL_2(\mathbb{R})$, *Differential Equation*, 50:11, 1541–1547, 2014.
10. (with Y. Sachkov) Superintegrability of Left-Invariant Sub-Riemannian Structures on Unimodular Three-Dimensional Lie Groups, *Differential Equation*, 51:11, 1476–1483, 2015.
11. (with E. Bekkers, R. Duits, G. Sanguinetti) A PDE Approach to Data-driven Sub-Riemannian Geodesics in $SE(2)$, *SIAM Journal on Imaging Sciences*, 8:4, 2740–2770, 2015.
12. (with R. Duits, A. Ghosh, T. Dela Haije) On sub-Riemannian geodesics in $SE(3)$ whose spatial projections do not have cusps, *Journal of Dynamical and Control Systems*, 22:4, 771–805, 2016.

13. (with A. Ardentov, Y. Sachkov) Relation between Euler's Elasticae and Sub-Riemannian Geodesics on $SE(2)$, *Regular and Chaotic Dynamics*, 21, pp 832–839, 2016.
14. (with R. Duits) A cortical based model for contour completion on the retinal sphere, *Program Systems: Theory and Applications*, 7:4, 231–247, 2017.
15. (with R. Duits, Yu. Sachkov, E. Bekkers, I. Beschastnyi) Tracking of Lines in Spherical Images via Sub-Riemannian Geodesics on $SO(3)$, *Journal of Mathematical Imaging and Vision*, 58:2, pp 239–264, 2017.
16. (with R. Duits, Yu. Sachkov, E. Bekkers, I. Beschastnyi) Sub-Riemannian geodesics in $SO(3)$ with application to vessel tracking in spherical images of retina, *Doklady Mathematics*, 95:2, 168–171, 2017.
17. (with V. Markasheva) Existence of Global Fundamental Solution to a Class of Fokker-Planck Equations, *Program Systems: Theory and Applications*, 8:4, 149–162, 2017.
18. (with A. Popov) Extremal Controls in the Sub-Riemannian Problem on the Group of Motions of Euclidean Space, *Regular and Chaotic Dynamics*, 22:8, 952–957, 2017.
19. On the step-2 nilpotent $(n, n(n+1)/2)$ sub-Riemannian structures (in Russian), *Program Systems: Theory and Applications*, 9:4, 327–368, 2018.
20. (with R. Duits, E. Bekkers) Fourier Transform on the Homogeneous Space of 3D Positions and Orientations for Exact Solutions to Linear PDEs, *Entropy*, 21(1), 38, 2019.
21. (with B. Franceschiello, G. Citti, A. Sarti) Geometrical Optical Illusion via Sub-Riemannian Geodesics in the Roto-Translation Group, *Differential Geometry and its Applications*, 65, 55–77, 2019.
22. Sub-Riemannian Geometry in Image Processing and Modelling of Human Vision, *Russian Journal of Nonlinear Dynamics*, 15:4, 561–568, 2019.
23. (with K. Putintseva) Image Processing Toolkit Inspired by Mechanisms of Human Visual Perception, *Program Systems: Theory and Applications*, 10:4(43), 111–139, 2019.
24. (with A. Popov) Asymptotics of Extremal Controls in the Sub-Riemannian Problem on the Group of Rigid Body Motions, *Russian Journal of Nonlinear Dynamics*, 16:1, 195–208, 2020.
25. (with V. A. Yumaguzhin, V. N. Yumaguzhina) On solutions to Fokker–Planck equations, *Optimal control, Itogi Nauki i Tekhniki. Ser. Sovrem. Mat. Pril. Temat. Obz.*, 178, pp. 102–111, 2020.
26. (with A. Ardentov) Motion planning of a mobile robot with a trailer via nilpotent approximation, *Automation and Remote Control*, 82, 73–92, 2021.
27. (with I.A. Galyaev) Liouville Integrability in a Four-Dimensional Model of the Visual Cortex, *Journal of Imaging*, 7(12):277, 2021.
28. Time minimization problem on the group of motions of a plane with admissible control in a half-disk, *Sbornik Mathematics*, 2022.
29. (with Yu.L. Sachkov) Extremal Trajectories in a Time-Optimal Problem on the Group of Motions of a Plane with Admissible Control in a Circular Sector, *Proceedings of the Steklov Institute of Mathematics*, 321, 200–207, 2023.

30. (with Yu.L. Sachkov) Time-Optimal Problem in the Roto-Translation Group with Admissible Control in a Circular Sector, *Mathematics*, 11(18):3931, 2023.

Proceedings of Conferences and Workshops

1. Riemannian geodesic lines on surfaces of revolution, (in Russian), In: *Proceedings of scientific conference "Program systems: Theory and applications"*, Pereslavl-Zalessky, pp. 39–52, 2006.
2. Extremal curves in the problem of a sphere rolling on a plane, (in Russian), In: *Proceedings of XI students conference of Pereslavl University*, Pereslavl-Zalessky, pp. 23–30, 2007.
3. Nilpotent approximations based solution of control problem for nonlinear five-dimensional systems, (in Russian), In: *Proceedings of XIII Annual Scientific-Practical Conference of Pereslavl University*, Pereslavl-Zalessky, pp. 117–131, 2009.
4. (with Yu. Sachkov, A. Ardentov) Constructive solution to control problem via nilpotent approximation method (in Russian), In: *Proceedings of Program Systems institute scientific conference "Program systems: Theory and applications"*, Pereslavl-Zalessky, pp. 5–23, 2009.
5. Asymptotic of Extremal trajectories in the plate-ball problem (in Russian), In: *Proceedings of the International Conference on Mathematical Control Theory and Mechanics (Suzdal, July 3-7, 2009)*, 158–165, 2011.
6. (with E. Bekkers, R. Duits, G. Sanguinetti) Data-Driven Sub-Riemannian Geodesics in SE(2). In: *Scale Space and Variational Methods in Computer Vision. Lecture Notes in Computer Science*, Vol. 9087, pp. 613–625, 2015.
7. (with G. Sanguinetti, R. Duits, E. Bekkers, M.H.J. Janssen, J.M. Mirebeau) Sub-Riemannian Fast Marching in SE(2), In: *Progress in Pattern Recognition, Image Analysis, Computer Vision, and Applications. Lecture Notes in Computer Science*, Vol. 9423, pp. 366–374, 2015.
8. (with B. Franceschiello, G. Citti, A. Sarti) Modelling of the Poggendorff Illusion via Sub-Riemannian Geodesics in the Roto-Translation Group, In: *New Trends in Image Analysis and Processing. ICIAP 2017. Lecture Notes in Computer Science*, Vol. 10590, pp. 37–47, 2017.
9. (with E. Bekkers, R. Duits, Yu. Sachkov) Vessel Tracking via Sub-Riemannian Geodesics on Projective Line Bundle, In: *Geometric Science of Information - GSI 2017. Lecture Notes in Computer Science*, Vol. 10589, pp. 773–781, 2017.
10. On Extremal Controls in the Sub-Riemannian Problem on the Group of Rigid Body Motions, In: *15th International Conference on Stability and Oscillations of Nonlinear Control Systems (Pyatnitskiy's Conference) (STAB)*, pp. 1-3, 2020.
11. Extremal Controls for the Duits Car, In: *Geometric Science of Information. GSI 2021. Lecture Notes in Computer Science*, Vol. 12829, pp. 73–81, 2021.
12. Extremal Trajectories of a Spherical Robot on Inhomogeneous Surfaces, In: *2021 International Conference "Nonlinearity, Information and Robotics" (NIR)*, 2021.
13. (with A. Podobryaev) Geodesic Flow of the Sub-Riemannian Structure of Engel Type with Strictly Abnormal Extremals, In: *16th International Conference on Stability and Oscillations of Nonlinear Control Systems (Pyatnitskiy's Conference)*, 2022, pp. 1-3.

Participation in Conferences and Workshops

1. Riemannian geodesic lines on surfaces of revolution, *Scientific conference "Program systems: Theory and applications"*, Pereslavl-Zalessky, Russia, 2006.
2. Extremal curves in the problem of a sphere rolling on a plane, *XI students conference of Pereslavl University*, Pereslavl-Zalessky, Russia, 2007.
3. Orientation control of the sphere rolling on the plane, *XII students conference of Pereslavl University*, Pereslavl-Zalessky, Russia, 2008.
4. Nilpotent approximations based solution of control problem for nonlinear five-dimensional systems, *XIII Annual Scientific-Practical Conference of Pereslavl University*, Pereslavl-Zalessky, Russia, 2009.
5. Approximate solution of motion planning problem for nonlinear five-dimensional systems, *International Conference on Mathematical Control Theory and Mechanics*, Suzdal, Russia, 2009.
6. Motion planning problem for nonlinear five-dimensional systems using nilpotent approximation, *Symposium with international participation "Control Theory: New Methods and Applications"*, Pereslavl-Zalessky, Russia, 2009.
7. Asymptotics of exponential mapping and limit behavior of Maxwell points in the plate-ball problem, *Workshop on Nonlinear Control and Singularities*, Porquerolles, France, 2010.
8. Asymptotics of Maxwell time in the plate-ball problem, *International student, postgraduate and young scientist conference "Lomonosov-2011"*, Moscow, Russia, 2011.
9. Cut time for rolling of a sphere along sinusoids of small amplitude, *The third traditional youth summer school "Control, Information and Optimization"*, Yaropolec, Russia, 2011.
10. Optimal inpainting parallel software for image inpainting via sub-Riemannian minimizers on the group of rototranslations, *International Conference on Mathematical Control Theory and Mechanics*, Suzdal, Russia, 2011.
11. Asymptotics of Maxwell time in the problem on optimal rolling of a sphere on a plane, *International Conference on Control and Optimization of Nonholonomic Systems*, Pereslavl-Zalessky, Russia, 2011.
12. Motion planning problem for nonlinear control systems in robotics, *The International Conference on Differential Equations and Dynamical Systems*, Suzdal, Russia, 2012.
13. Optimal control of a mobile robot on a plane, *Control in engineering, ergatic, organizational and network systems*, Saint Petersburg, Russia, 2012.
14. Motion planning problem for some control systems applied in robotics, *SADCO Summer School and Workshop "New Trends in Optimal Control"*, Ravello, Italy, 2012.
15. Optimal control problem for left-invariant sub-Riemannian structures on the special linear group *The International Conference on Mathematical Control Theory and Mechanics*, Suzdal, Russia, 2013.
16. Integrability of the left-invariant sub-Riemannian structures on the special linear group, *Control and optimization of nonholonomic systems*, Pereslavl-Zalessky, Russia, 2013.

17. Integrability of invariant sub-Riemannian structures on 3D Lie groups, *Differential Geometry and its Applications*, Brno, Czech Republic, 2013.
18. Analysis of cusps and characterization of the existence set in an association field model on the retinal sphere, *International Conference on Differential Equations and Dynamical Systems*, Suzdal, Russia, 2014.
19. Solutions to an association field model on the retinal sphere: sub-Riemannian geodesics in $SO(3)$ with cusplless spherical projections, *Workshop on Geometrical Models in Vision*, Paris, France, 2014.
20. Sub-Riemannian Problems on 3D Lie Groups with Applications to Retinal Image Processing, *MANET Workshop on Sub-Riemannian Analysis, PDE and Applications*, Bern, Switzerland, 2015.
21. Data-driven Sub-Riemannian Geodesics in $SE(2)$, *Fifth International Conference on Scale Space and Variational Methods in Computer Vision*, Lage Cap Ferret, France, 2015.
22. Sub-Riemannian Problems on 3D Lie Groups with Applications to Retinal Image Processing, *International Conference on Mathematical Control Theory and Mechanics*, Suzdal, Russia, 2015.
23. Sub-Riemannian Problems on 3D Lie Groups with Applications to Retinal Image Processing, *School and Workshop GEOMETRY, DYNAMICS AND CONTROL*, Maksimikha, Lake Baikal, Russia, 2015.
24. Sub-Riemannian Problems on 3D Lie Groups with Applications to Retinal Image Processing, *Scientific Meeting "Nonholonomic days in Pereslavl"*, Pereslavl-Zalessky, Russia, 2015.
25. Sub-Riemannian Problems on Lie Groups with Applications to Medical Image Processing, *Mid-Term Review Meeting of MANET Project*, Helsinki, Finland, 2015.
26. Tracking of Lines in Spherical Images via Sub-Riemannian Geodesics on $SO(3)$, *Sixth International Conference "Geometry, Dynamics, Integrable Systems" GDIS 2016*, Izhevsk, Russia, 2016.
27. Tracking of Lines in Spherical Images via Sub-Riemannian Geodesics on $SO(3)$, *International Conference on Differential Equations and Dynamical Systems*, Suzdal, Russia, 2016.
28. Tracking of Lines in Spherical Images via Sub-Riemannian Geodesics in $SO(3)$, *International Workshop on Geometry, PDE's and Lie Groups in Image Analysis*, Eindhoven, The Netherlands, 2016.
29. Sub-Riemannian geodesics in $SO(3)$ with application to vessel tracking in spherical images of retina, *Geometric Analysis and Control Theory*, Novosibirsk, Russia, 2016.
30. Motion planning of a mobile robot with a trailer via nilpotent approximation, *Mathematical Control Theory*, Porquerolles, France, 2017.
31. A Cortical Based Model for Contour Completion on the Retinal Sphere, *International Conference on Mathematical Control Theory and Mechanics*, Suzdal, Russia, 2017.
32. Modelling of the Poggendorff Illusion via Sub-Riemannian Geodesics in the Roto-Translation Group, *First International Workshop on Brain-Inspired Computer Vision*, Catania, Italy, 2017.

33. Vessel Tracking via Sub-Riemannian Geodesics on Projective Line Bundle, *3rd conference on Geometric Science of Information*, Paris, France, 2017.
34. Sub-Riemannian Geodesics on the Group of Motions of Euclidean Space, *Winter Geometry School-Conference*, Pereslavl-Zalessky, Russia, 2018.
35. Sub-Riemannian Geodesics on the Group of Motions of Euclidean Space, *VII-th International Conference "Geometry, Dynamics, Integrable Systems (GDIS 2018)"*, Moscow, Russia, 2018.
36. Sub-Riemannian Geodesics on the Group of Motions of Euclidean Space, *The International Conference on Differential Equations and Dynamical Systems*, Suzdal, Russia, 2018.
37. Sub-Riemannian Geodesics on the Group of Rigid Body Motions, *International Conference "Optimal Control and Differential Games" dedicated to the 110th anniversary of L. S. Pontryagin*, Moscow, Russia, 2018.
38. Sub-Riemannian Geometry in Image Processing, *Conference "Subriemannian Geometry and Beyond, II"*, Jyvaskya, Finland, 2019.
39. Sub-Riemannian Geometry in Image Processing and Modelling of Human Visual System, *International Conference "Scientific Heritage of Sergey A. Chaplygin: Nonholonomic mechanics, vortex structures and hydrodynamics"*, Cheboksary, Russia, 2019.
40. On the Cut Locus on Step-2 Free Carnot Groups, *XIII All-Russian Meeting on Control Sciences (VSPU 2019)*, Moscow, Russia, 2019.
41. Sub-Riemannian Geometry in Image Processing and Modelling of Human Visual System, *International Conference on Geometric Analysis in honor of the 90th anniversary of academician Yu.G. Reshetnyak*, Novosibirsk, Russia, 2019.
42. On the Cut Locus on Step-2 Free Carnot Groups, *National Supercomputing Forum (NSCF-2019)*, Pereslavl-Zalessky, Russia, 2019.
43. On Extremal Controls in the Sub-Riemannian Problem on the Group of Rigid Body Motions, *XV International Conference "Stability and Oscillations of Nonlinear Control Systems" (Pyatnitskiy's Conference)*, Moscow, Russia, 2020.
44. Asymptotics of Extremal Controls in the Sub-Riemannian Problem on the Group of Rigid Body Motions, *The International Conference on Differential Equations and Dynamical Systems*, Suzdal, Russia, 2020.
45. On Extremal Controls in the Sub-Riemannian Problem on the Group of Rigid Body Motions, *The International Conference on Differential Equations and Dynamical Systems*, Suzdal, Russia, 2020.
46. Time minimization problem for a left-invariant control system on the group of motions of a plane with admissible control in a semicircle, *National Supercomputing Forum (NSCF-2020)*, Pereslavl-Zalessky, Russia, 2020.
47. Curvature analysis of image contours, *National Supercomputing Forum (NSCF-2020)*, Pereslavl-Zalessky, Russia, 2020.
48. Time minimization problem on the group of motions of a plane with admissible control in a half-disk, *Geometric methods in control theory and mathematical physics (ConfGMDE-2021)*, Ryazan, 2021.

49. Liouville integrability in a four-dimensional model of the visual cortex, *The mathematics of vision: from cortical-inspired modelling to perception. International Conference on Mathematical Neuroscience*, Digital Edition, 2021.
50. Time minimization problem on the group of motions of a plane with admissible control in a half-disk, *Scientific Meeting Geometric and quantum control*, Sirius, Sochi, 2021.
51. Extremal controls for the Duits car, *5th conference on Geometric Science of Information*, Paris, France, 2021.
52. Extremal Trajectories of a Spherical Robot on Inhomogeneous Surfaces, *The Second International Conference "Nonlinearity, Information and Robotics"*, Innopolis, Russia, 2021.
53. On the hyperbolic model of visual color perception, *National Supercomputing Forum (NSCF-2021)*, Pereslavl-Zalessky, Russia, 2021.
54. Geodesic flow of the sub-Riemannian structure of Engel Type with strictly abnormal extremals, *XVI International conference "Stability and Oscillations of Nonlinear Control Systems" (Pyatnitskiy's conference)*, Moscow, 2022.
55. Extremal trajectories in the left-invariant time minimization problem on the group of motions of a plane with admissible control in a circular sector, *XVI International conference "Stability and Oscillations of Nonlinear Control Systems" (Pyatnitskiy's conference)*, Moscow, 2022. *Differential equations and optimal control. International Conference dedicated to the centenary of the birth of Academician Evgenii Frolovich Mishchenko*, Moscow, 2022.
56. Time minimization problem on the Heisenberg group with admissible control in a half-disk, *The International Conference on Differential Equations and Dynamical Systems*, Suzdal, Russia, 2022.
57. Time minimization problem on the group of motions of a plane with admissible control in a circular sector, *National Supercomputing Forum (NSCF-2022)*, Pereslavl-Zalessky, Russia, 2022.
58. Time minimization problem on the group of motions of a plane with admissible control in a circular sector, *Geometry and Control in Cortona. In honor of Andrei Agrachev's 70th birthday*, Cortona, Italy, 2023.
59. Time minimization problem on the group of motions of a plane with admissible control in a circular sector, *Voronezh spring mathematical school "Pontryagin Readings"*, Voronezh, Russia, 2023.
60. Time minimization problem on the group of motions of a plane with admissible control in a circular sector, *International Summer Scientific School "High Speed Hydrodynamics"*, Cheboksary, Russia, 2023.
61. Time minimization problem on the group of motions of a plane with admissible control in a circular sector, *National Supercomputing Forum (NSCF-2023)*, Pereslavl-Zalessky, Russia, 2023.
62. Sub-Riemannian problem on the central extension of the group of motions of a plane, *International conference systems analysis: modeling and control. In memory of academician A. V. Kryazhimskiy*, Moscow, 2024.