

Igor Zelenko

CURRICULUM VITAE

Name: Igor Zelenko

Date of birth: 13 July, 1972

Place of birth: Edinca, Moldova, former USSR

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Education:

- – June 2002 – PhD degree, Department of Mathematics, Technion-Israel Institute of Technology

PhD thesis title: Invariants of curves in the Lagrange Grassmannian and differential geometry of smooth control systems

– Supervisors: Alexander Ioffe, Andrei Agrachev.
- – 1998 – Master degree, Department of Mathematics, Technion - Israel Institute of Technology.

- Master thesis title: Nonregular abnormal geodesics of 2-distribution: existence, second variation and rigidity
- Supervisor: Michael Zhitomirskii.
- – 1994 – BA degree, Department of Mathematics, Technion - Israel Institute of Technology.

Army service: 1994-1996 (Israel Defence Forces)

Research subject.

Differential geometry and Geometric Control Theory.

The main direction of my current research is the construction of the curvature-type differential invariants and equivalence problem for a wide class of geometric structures and control systems on manifolds, especially for

- nonholonomic vector distributions and fields of cones with application to geometry of variational problems, ODE's and PDE's;
- sub-Riemannian and sub-Finslerian structures on nonholonomic vector distributions with application to Optimal Control and Physics (for example, to Yang-Mills fields)

The approach to these equivalence problems is based on the study of differential geometry of curves in Lagrangian Grassmannians and in spaces of isotropic and co-isotropic flags in a linear symplectic space. Using this and other approaches we also work on the following topics

- optimality properties of extremals of optimal control problems (comparison theorems, i.e. an estimation of intervals of optimality in terms of the curvature-type invariants);
- qualitative study of Hamiltonian systems (via the notion of generalized curvature of Hamiltonian systems).

Among other topics of my current research are

- geodesic (projective) equivalence of sub-Riemannian metrics ;

- sub-Riemannian analogs of Laplace-Beltrami operator and asymptotic of the corresponding heat kernels;
- algebraic-geometric structures, appearing in context of curvature type invariants;
- singularities of caustics and wave fronts, appearing in sub-Riemannian Geometry;
- geometry of second order PDE's via geometry of hypersurfaces in Lagrange Grassmannians;
- invariant description of flat control systems;
- state-feedback equivalence of control-affine systems (or equivalence of affine subbundles of the tangent bundle);

Professional experience:

- August 2008– tenure-track Assistant Professor at Department of Mathematics, Texas A&M University, College Station, USA
- September 2005-August 2008– a long term Visiting Associate Professor at International School for Advanced Studies (SISSA-ISAS), Trieste, Italy;
- August 2002– August 2005– Research Associate at International School for Advanced Studies (SISSA-ISAS), Trieste, Italy.

Teaching experience:

- Spring 2009– Differential Geometry of Curves and Surfaces, MATH 439-Texas A&M University
- Fall 2008– Advanced Calculus -I, MATH 409-Texas A&M University;
- November 2006- March 2007 - Lecturer in the graduate course “Geometric Control Theory” at SISSA, 27 lectures, including:
 - a. Controllability: orbits of families of vector fields (Nagano-Sussmann, Rashevsky-Chow, Frobenius theorems), the structure of attainable sets for bracket-generating systems (accessibility, relaxation, Poisson stability) with application to control of rigid body;

- b.** Optimal Control Theory: existence theorems (Filippov theorem), Pontryagin Maximum Principle, linear time-optimal problems, linear-quadratic problems, dynamic programming and Hamilton-Jacobi equation, second-order optimality conditions;
 - c.** State-feedback equivalence of control systems (mainly state and state-feedback linearizability).
- November 2005- March 2006 - Lecturer in the graduate course “Introduction to Dynamical Systems” at SISSA, 25 lectures, including:
 - a.** Local theory of hyperbolic stationary points of vector fields: existence of stable and unstable manifolds (Hadamard-Perron theorem); topological equivalence to the linearization (Grobman-Hartman theorem), local structural stability; generalization of Grobman-Hartman theorem to the non-hyperbolic case (Shoshitaishvili reduction principle)
 - b.** Normal forms in the neighborhood of stationary points of vector fields: resonances, formal normal forms (Poincare-Dulac theorem); relation between smooth and formal equivalence via homotopy (deformation) method (Sternberg and Chen theorems); small denominators and biholomorphic linearization (Siegel theorems, elements of KAM theory)
- October 2002– January 2003– Lecturer and teaching assistant in the course “*Optimization and Control Theory*” at the Master Program of ICTP-International Center for Theoretical Physics, Trieste, Italy;
- 1993 – 1994, 1996 – 2002– Teaching Assistant in Complex Analysis, various courses of Calculus (first, second and third semesters), Linear Algebra, ODEs and PDEs both for mathematicians and engineers at the Technion-Israel Institute of Technology.

Students

- 1.** Currently I am a supervisor of Chengbo Li, who is a forth year student on the PhD program of SISSA . We have written two joint papers (see [1] and [17] below) and we are completing now one more paper [20]. The first paper is already published.
- 2.** I was (non-officially) a co-supervisor of Natalia Chtcherbakova, who defended her PhD thesis “Curvature-type invariants of geometrical control

theory in problems of hamiltonian dynamics” at SISSA in 2004 (our joint paper with her and A. Agrachev (see [8] below) was a part of her thesis).

3. I was a supervisor of E. A. Kwessi Nyandjou in the Diploma program of ICTP- International Center for Theoretical Physics, Trieste, Italy in the academic year of 2006/2007. The title of his diploma thesis was ”Generalized Sturm Theorem for self-adjoint differential operators of higher order”. Now we are preparing a joint paper based on this thesis (see [22] below).

4. I was a supervisor of Y. Roodgar Amoli in the Diploma program of ICTP- International Center for Theoretical Physics, Trieste, Italy in the academic year of 2005/2006. The title of his diploma thesis was “On quaternionic model and symmetries of vector distributions generated by rolling of spheres”

5. I was a co-supervisor (non-officially) of Wojciech Krynski, who defended his PhD thesis in Spring 2008 at Banach Mathematical Center, Poland. Now we are preparing a joint paper [19], part of which was included in his PhD thesis.

List of published and accepted papers:

1. *On Tanaka’s prolongation procedure for filtered structures of constant type*, Symmetry, Integrability and Geometry: Methods and Applications (SIGMA), special issue ”Élie Cartan and Differential Geometry”, doi:10.3842/SIGMA.2009.094, 0906.0560 v3 [math.DG], 21 pages.

2. (Jointly with B. Doubrov) *On local geometry of nonholonomic rank 2 distributions*, Journal of London Mathematical Society, accepted for publication, doi: 10.1112/jlms/jdp044 arxiv math.DG/0703662, 21 pages .

3. (Jointly with Chengbo Li) *Differential geometry of curves in Lagrange Grassmannians with given Young diagram*, Differential Geometry and Its Applications, doi: 10.1112/jlms/jdp044, arXiv:0708.1100v1 [math.DG], 26 page

4. (Jointly with Chengbo Li) *Parametrized curves in Lagrange Grassmannians*, C.R. Acad. Sci. Paris, Ser. I, Vol. 345, Issue 11 (2007), 647-652, presented by Pierre Deligne.

5. (Jointly with A. Agrachev) *On feedback classification of control-affine systems with one and two-dimensional inputs*, SIAM Journal on Control and Optimization, Vol. 46, Issue 4 (2007), 1431-1460.

- 6.** (Jointly with B. Doubrov) *A canonical frame for nonholonomic rank two distributions of maximal class*, C.R. Acad. Sci. Paris, Ser. I, Vol. 342, Issue 8 (15 April 2006), 589-594 , presented by Michael Gromov (see also arxiv math. DG/0504319).
- 7.** *Variational Approach to Differential Invariants of Rank 2 Vector Distributions*, Differential Geometry and Its Applications, Vol. 24, Issue 3 (May 2006), 235-259, communicated by Robert Bryant (the long version in arxiv math. DG/0402171).
- 8.** *Fundamental form and Cartan's tensor of (2,5)-distributions coincide*, J. Dynamical and Control Systems, Vol.12, No. 2, April 2006, 247-276 (see also arxiv math. DG/0402195).
- 9.** (Jointly with A. Agrachev) *Nurowski's conformal structures for (2,5)-distributions via dynamics of abnormal extremals*, Proceedings of RIMS Symposium on "Developments of Cartan Geometry and Related Mathematical Problems", "RIMS Kokyuroku" series 1502, 204-218, arxiv math.DG/0605059.
- 10.** *Complete systems of invariants for rank 1 curves in Lagrange Grassmannians*, Differential Geom. Application, Proc. Conf. Prague, 2005, pp 365-379, Charles University, Prague (see also arxiv math. DG/0411190).
- 11.** (Jointly with A. Agrachev, N. Chtcherbakova), *On curvatures and focal points of dynamical Lagrangian distributions and their reductions by first integrals*, J. Dynamical and Control Systems, **11**(2005), No.3, 297-327.
- 12.** *On geodesic equivalence of Riemannian metrics and sub-Riemannian metrics on distributions of corank 1*, Journal of Mathematical Sciences, Vol. 135, Number 4 (June 2006), 3168 - 3194.
- 13.** (Jointly with A. Agrachev) *Geometry of Jacobi curves. I*, J. Dynamical and Control systems, **8**(2002),No. 1, 93-140.
- 14.** (Jointly with A. Agrachev) *Geometry of Jacobi curves . II*, J. Dynamical and Control systems,**8**(2002), No. 2, 167-215.
- 15.** (Jointly with A. Agrachev) *Principle Invariants of Jacobi curves*, In the book: Nonlinear Control in the Year 2000, v.1, A. Isidori, F. Lamnabhi-Lagarrigue & W.Respondek, Eds, Lecture Notes in Control and Information Sciences 258, Springer, 2001, 9-22.
- 16.** *Nonregular abnormal extremals of 2-distribution: existence, second variation and rigidity*, J. Dynamical and Control systems , 5(1999), No. 3,

347-383.

17. (Jointly with M.Zhitomirskii) *Rigid paths of generic 2-distributions on 3-manifolds*, Duke Mathematical Journal, Vol. 79, No. 2, 1995, 281-307.

Preprints

18. (Jointly with B. Doubrov) *On local geometry of rank 3 distributions with 6-dimensional square*, submitted to Communications in Analysis and Geometry, 0807.3267 v1 [math.DG], 40 pages

19. (Jointly with Chengbo Li) *Jacobi Equations and Comparison Theorems for Corank 1 sub-Riemannian Structures with Symmetries*, 0908.4397 v1 [math.DG], submitted to Journal of Geometry and Physics, 27 pages,

Papers in preparation:

20. (Jointly with B. Doubrov) *Equivalence of variational problems of higher order*.

21. (Jointly with W. Krynski) *On equivalence problem for vector distributions of corank two and odd rank with maximal Kronecker index*.

22. *Index of second variation and symplectic invariants of Jacobi curves of extremals*.

23. (Jointly with B. Doubrov) *Symplectification, Generalized Tanaka prolongation, and distributions controllable by abnormal extremal trajectories*

24. (Jointly with B. Kruglikov) *Weyl theorem for sub-Riemannian structures*.

Papers in plan:

25. (Jointly with B. Doubrov) *Symplectification, Generalized Tanaka prolongation, and distributions of maximal class*;

26. (Jointly with Chengbo Li) *On sub-Riemannian metrics associated with Yang-Mills fields*.

Visits:

1. University of Tromso, Norway (Prof. B. Kruglikov) October-beginning of November 2007;
2. Institute for Advanced Study, Princeton, USA (Prof. P. Griffiths), March 2007;
3. Eduard Cech Center for Algebra and Geometry at Masaryk University of Brno, Czech Republic (Prof. J. Slovák), May 2006;
4. RIMS Kyoto and Nara Women University, Nara, Japan (Prof. T. Morimoto), October-November 2005;
5. INRIA, Nice, France (Prof. J.-B. Pomet), April 2004 and April 2005;
6. Weizmann Institute of Science, Rehovot (Prof. S. Yakovenko and V. Rom-Kedar), and Ben-Gurion University, Beer-Sheva (Prof. A. Besser), Israel, December 2003;
7. SISSA, Trieste, Italy (Prof. A. Agrachev) several times between September 1999 and February 2002;
8. Steklov Institute of Mathematics (Prof. A. Agrachev), Moscow, Russia, October 1998;
9. University of California, Santa Cruz, USA, (Prof. R. Montgomery), June 1997.

Talks in International Conferences:

1. International conference Differential Equations and Topology dedicated to Centennial Anniversary of L. S. Pontryagin, Moscow State University, June 17-22, 2008

Title of the talk: *Contact sub-Riemannian structures as a generalization of almost Kahlerian structures*

2. 10th Conference on Differential Geometry and its Applications, Olomouc, Czech Republic, August 27-31, 2007,

Title of the talk: *Differential geometry of curves in Lagrange Grassmannians with given Young diagram*

3. Workshop on Control, Optimization and Stability of non-linear systems: geometric and analytic methods", Trieste, Italy, May 30 - June 1, 2007 Title of the talk: *Parametrized curves in Lagrange Grassmannians*

4. Midwest Geometry Conference (in honor of Thomas P. Branson)
University of Iowa, Iowa City, USA, May 18 - 20, 2007

Title of the talk: *On Local Geometry of Nonholonomic Vector Distributions*

5. Workshop “Geometry of vector distributions, differential equations, and variational problems”, SISSA, Trieste, December 13-15 of 2006

Title of the talk: *Canonical frames for vector distributions of rank two and three*

6. 2006 IMA Summer Program “Symmetries and Overdetermined Systems of Partial Differential Equations”, IMA (Institute for Mathematics and its Applications), Minneapolis, USA, July 17-August 4, 2006.

Title of the talk: *Symplectification procedure for the equivalence problem of vector distributions;*

7. Workshop “Geometry in Nara”, Nara, Japan, October 2005;

Title of the talk: *Symplectification procedure for the equivalence problem of vector distributions;*

8. RIMS Symposium on Developments of Cartan Geometry and Related Mathematical Problems, Kyoto, Japan, October 2005;

Title of the talk: *On canonical frames for vector distributions;*

9. 25th Winter School on Geometry and Physics, Srni, Czech Republic, January 2005;

Title of the talk: *An intrinsic number of functional invariants and classification of affine control systems;*

10. 9th Conference on Differential Geometry and its Applications, Prague, Czech Republic, August-September 2004;

Title of the talk: *Differential geometry of curves in Lagrange Grassmannians with application to invariants of rank 2 vector distributions;*

11. First CTS workshop, Coimbra, Portugal, July 2004;

Title of the talk: *On feedback classification of four-dimensional affine*

control systems with one or two inputs;

12. Workshop of Banach Center Research Group on “Geometry of Control Systems and Distributions”, May 2004;

Series of three talks with the title: *Differential invariants of rank 2 distributions;*

13. Trimester on ”Dynamical and Control Systems” SISSA-ICTP, Italy, Sept. 8 - Dec. 7, 2003;

Series of two talks with the title: *Dynamical Approach to Problem of Equivalence of Rank 2 Vector Distributions, I and II;*

14. Current Geometry, The International Conference on problems and trends of contemporary geometry Naples, Italy, June 2003

Title of the talk: *A Variational Approach to Differential Invariants;*

15. Geometry in Nonlinear Control, Banach Center Workshop, Bedlewo, Poland, June 2003;

Title of the talk: *Fundamental form and projective curvature of rank 2 distributions;*

16. The second NCN (Nonlinear Control Network) workshop, Supélec, Paris, France, June 2000;

Title of the talk: *Geometry of Jacobi curves;*

17. International Conference in the Calculus of Variations, Technion, Haifa, March 1998;

Title of the talk: *Nonregular abnormal geodesics of 2-distribution: existence, second variation and rigidity.*

Selected seminar talks

1. Seminar on Complex Algebraic Geometry, Institute for Advanced Studies, Princeton, USA, March 2007;

Title of the talk: *Canonical frames for nonholonomic vector distribu-*

tions;

2. The Weizmann Institute of Science, Faculty of Mathematics and Computer Science, Rehovot, Israel, June 2007;

Title of the talk: *Differential geometry of curves in Lagrange Grassmannians with given Young diagram and comparison theorems*

3. Seminar on Differential equations and Dynamical systems, Steklov Institute of Mathematics, Moscow, Russia, October 1998

Title of the talk: *Nonregular abnormal geodesics of 2-distribution: existence, second variation and rigidity.*

Organization of conferences:

1. I was the initiator and the main organizer of the workshop “Geometry of vector distributions, differential equations, and variational problems”, which took place at SISSA in December 13-15 of 2006. The main financial support was given by Central European Initiative (CEI) funds after the approval of my proposal. For the program, list of the participants, and etc see the webpage of the workshop

<http://people.sissa.it/zelenko/CEIHomepage.html>

2. I was one of the organizer of Workshop on Control, Optimization and Stability of non-linear systems: geometric and analytic methods”, which took place at SISSA, Trieste, Italy in May 30-June 1 2007.

3. I was one of the local organizers of Trimester on ”Dynamical and Control Systems” SISSA-ICTP, Italy, Sept. 8 - Dec. 7, 2003. I was responsible for coordination of about 40 seminar talks, taking plays in this event.

Participation in Editorial boards:

I am a member of the advisory board of Polimetrica Publisher for the field of Geometry of Differential Equations.

Reviewing and Refereeing

Refereed for these journals:

Journal of Dynamical and Control Systems ; Journal of Mathematical Analysis and Applications; Journal of Geometry and Physics; Communications on Pure and Applied Mathematics; Duke Mathematical Journal

Grants and fellowships:

1. Research Grant of Italian Ministry of Education and Science - 2005-2006, 2007;
2. Grants of Central European Initiative (CEI) for organization of the workshop during the year 2006 and for post-doc positions in the year 2008;
3. Marie Curie Control Training Site (CTS) fellowship - February-April 2002, host: SISSA, Trieste, Italy;
4. European Training and Mobility Research fellowships - September-December 1999 (Rome University "La Sapienza") and September-October 2001 (Florence University)
5. I was supported by Binational Israel-USA Science Foundation (BSF) grant-1994-1997.

Awards:

- Wolf prize for PhD students – Hebrew University, Jerusalem, 2001
- Gutwirth Prize for graduate students – Technion, Haifa, 1997 and 2000