Erik J. **Bekkers**

Post-Doc Researcher · Mathematical/Medical Image Analysis and AI Expert

Address: Distelvlinderlaan 45, 5691RM, Son, the Netherlands · *Date of birth*: 5 June 1987 · *Nationality*: Dutch

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Profile

I am an enthusiastic inter-disciplinary researcher with a strong drive to solve fundamental problems in artificial intelligence, computer vision, and medical image analysis. In the past and present I have been able to pursue my ambitions with a fortunate position between the academic fields of *mathematics and engineering* on the one hand and *industry and the medical clinic* on the other hand. My current research line is on machine learning using Lie group theory and principles from visual psychology (see e.g. [13, 2]).

Employment History

Eindhoven University of Technology (Mathematics and Computer Science) *De Rondom 70, 5612 AP, Eindhoven, the Netherlands*

Postdoc Researcher *Sept. 2016 - Present*
- **Postdoc**: in the ERC-StG "Lie Analysis" project of dr.ir. Remco Duits at the dept. of Applied Mathematics and Computer Science.
- **Tasks**: Develop machine learning and image analysis algorithms for medical images using geometric mathematical techniques · Special focus on the analysis, tracking and segmentation of curvilinear structures (lines, vessels, neurons) in 2D and 3D data · Author and co-author papers in computer vision, medical/mathematical image analysis, and applied math journals · Supervising PhD students · Teaching (graduate and undergraduate level Applied Mathematics and Computer Science).

i-Optics BV (EasyScan BV) *Mauritskade 35, 2514HD, the Hague, the Netherlands*

Research Engineer *Jan. 2013 - Sept. 2016*
- **Research Engineer + PhD**: This work was conducted in combination with a PhD at Eindhoven University of Technology.
- **Tasks**: Quantify and improve image quality of EasyScan (SLO fundus camera) images · Data processing (from raw data to images) · Quantification of camera properties (e.g. the field curvature of lenses) · Investigate automated referral systems · Software testing.

Eindhoven University of Technology (Biomedical Engineering) *De Rondom 70, 5612 AP, Eindhoven, the Netherlands*

PhD Candidate *Jan. 2013 - Sept. 2016*
- **Tasks**: See education.

Eindhoven University of Technology (Biomedical Engineering) *De Rondom 70, 5612 AP, Eindhoven, the Netherlands*

Assistent Researcher *Sept. 2012 - Dec. 2012*
- **Tasks**: Supervising students · Managing and organizing code · Research

Education

PhD (*Cum Laude*) - Medical Image Analysis
       Biomedical Engineering (Eindhoven University of Technology) *Eindhoven, the Netherlands*

Jan. 2013 - Jan. 2017
- **Title**: Retinal Image Analysis using Sub-Riemannian Geometry in SE(2). https://erikbekkers.bitbucket.io/data/pdf/Bekkers_PhD_Thesis_Compressed.pdf
- **Promotor/copromotor**: Prof.dr.ir. Bart ter Haar Romeny/dr.ir. Remco Duits.
- **Topic**: Development of new mathematical techniques for automated retinal image analysis.
- **Mathematical tools used**: Differential geometry · Lie group theory · Variational calculus · PDE's · Numerical methods.
- **Image analysis problems**: Vessel tracking · Object recognition · Segmentation · Curvature analysis · Biomarkers.
- **Main results**: A new method for curvature penalized shortest path computation · A new fast and robust method for object detection based on orientation patterns · New clinical biomarkers for diabetes and hypertension based on vessel curvature analysis.

MSc - Biomedical Engineering (Eindhoven University of Technology) *Eindhoven, the Netherlands*

Sept. 2009 - Sept. 2012
- **Thesis** (9 months): A new vessel tracking method based on orientation scores · Conducted at the Biomedical Image Analysis lab (prof.dr.ir. Bart ter Haar Romeny) and at University Eye Clinic Maastricht (dr. Tos Berendschot)
- **Internship** (6 months): 3D Deformation recovery of a collapsed pig lung from CT data of multiple time phases · Conducted at Osaka University (Japan), Medical Imaging lab (prof. Yoshinobu Sato)
- **Internship** (3 months): Accuracy estimation of stereotactic frame registration by simulated MR volumes · Conducted at Philips Research, High-Tech Campus Eindhoven
- **Specialization**: Additional specialization in medical image analysis with courses on the physics behind imaging modalities, image analysis, pattern recognition, and differential geometry. Training in Matlab and Mathematica.

BSc - Biomedical Engineering (Eindhoven University of Technology) *Eindhoven, the Netherlands*
Sept 2006 - Sept. 2009

- **Education**: Followed a broad engineering curriculum including mathematics (linear algebra, (vector) calculus, statistics), physics (optics, electromagnetism, mechanical dynamics, thermodynamics), chemistry (organic chemistry, material science), electrical engineering, programming skills (Python, Matlab, Mathematica) and the basics of medical sciences.

Propreadeutic - Mechanical Engineering (Eindhoven University of Technology) *Eindhoven, the Netherlands*
Sept 2005 - Sept. 2006

Prizes and Awards

- **Young Scientist Award** awarded by the Medical Image Computing and Computer Assisted Interventions (MICCAI) society in 2018.
- **Philips Impact Award** awarded at the international conference on Medical Imaging with Deep Learning (MIDL) 2018.
- **Nominated for TU/e best Ph.D. Thesis Award 2018**.
- **Cum Laude** for my Ph.D. thesis.

Extracurricular Activity

- **Research visits**: *2019 (March) - Institut Henri Poincaré, Paris, France*. One month planned research visit on invitation of Gabriel Peyre · *2018 - ICTEAM research institute, Université Catholique Louvain, Belgium*. Half a week research visit on invitation of prof. Pierre-Antoine Absil · *2018 - Computational Data Analysis Lab, Universität Bremen, Germany*. One week research visit on invitation of Prof. Dr. Emily King and Rafaël Reisenhofer · *2017 - Université Paris Dauphine, CNRS, Paris, France*. Spent one week in the lab of Laurent Cohen. The visit resulted in the journal paper [3].
- **Conferences**: MICCAI 2018 (*Young Scientist Award*, oral - *4% accept rate*) · MIDL 2018 (poster - *Philips Impact Award*) · NMC 2018 (oral+poster) · MIA 2017 (poster) · SSVM 2017 (poster) · GAMM 2016 (invited oral) · MICCAI 2015 (3x workshop poster presentation) · SSVM 2015 (poster) · EMMCVPR 2015 (oral) · MICCAI 2014 (poster) · ICIAR 2014 (oral).
- **Department Council**: Secretary of the department council for the department of Mathematics and Computer Science (TU/e). The department council is the department's co-determination body in which its members discuss the general state of affairs within the department with the departmental board, produce proposals and make viewpoints heard.
- **Organization of workshops and symposia**: 3-day "International Workshop on Geometry, PDE's and Lie Groups in Image Analysis" together with Remco Duits, Andrea Fuster and Yuri Sachkov · The annual medical imaging symposium for PhD students (MISP) in 2016 (Attended previous editions).
- **Summer schools**: 3rd Biomedical Image Analysis Summer School (Paris 2015) · NFBIA Summer School on Medical Image Analysis (Nijmegen, 2015) · International Summer School on Brain-inspired Computer Vision (Shenyang, China, 2012 & 2013) · ASCII course "Advanced pattern Recognition" in 2013.
- **NVPHBV**: Active member of the dutch association for pattern recognition and image analysis (NVPHBV) since 2013.
- **Student supervision**: In the past and present I have supervised multiple BSc and MSc students/interns at Eindhoven University of Technology and previously also at i-Optics BV.

Research Interests and Hobbies

- **Research Interests**: Machine learning · Differential geometry · Variational methods · Visual perception · Medical imaging.
- **Hobbies**: Listening to and making music (http://www.horsefashionmusic.nl) · Yoga · Board games.

Language and Skills

- **Programming/scripting/writing languages**: Wolfram Mathematica (expert) · Matlab (expert) · Latex (expert) · Python (advanced) · C++ (advanced) · Linux (beginner)
- **Language**: Dutch (native) · English (fluent)

Publications

Journal Papers

[1] R. Duits, E. J. **Bekkers**, and A. Mashtakov. "Fourier Transform on the Homogeneous Space of 3D Positions and Orientations for Exact Solutions to Linear Parabolic and (Hypo-) Elliptic PDEs". In: *arXiv preprint arXiv:1811.00363* (2018).

[2] E. J. **Bekkers**, M. Loog, B. M. ter Haar Romeny, and R. Duits. "Template matching via densities on the roto-translation group". In: *IEEE transactions on pattern analysis and machine intelligence* 40.2 (2018), pp. 452–466.

[3] E. J. **Bekkers**, D. Chen, and J. M. Portegies. "Nilpotent Approximations of Sub-Riemannian Distances for Fast Perceptual Grouping of Blood Vessels in 2D and 3D". In: *Journal of Mathematical Imaging and Vision* 60.6 (2018), pp. 882–899.

[4] M. M. H. J. Janssen, A. J. E. M. Janssen, E. J. **Bekkers**, J. Oliván Bescós, and R. Duits. "Design and Processing of Invertible Orientation Scores of 3D Images". In: *Journal of Mathematical Imaging and Vision* (2018), pp. 1–32.

[5] J. Zhang, E. J. **Bekkers**, D. Chen, T. T. J. M. Berendschot, J. Schouten, J. P. W. Pluim, Y. Shi, B. Dashtbozorg, and B. M. ter Haar Romeny. "Reconnection of Interrupted Curvilinear Structures via Cortically Inspired Completion for Ophthalmologic Images". In: *IEEE Transactions on Biomedical Engineering* 65.5 (2018), pp. 1151–1165.

[6] J. Zhang, Y. Chen, E. J. **Bekkers**, M. Wang, B. Dashtbozorg, and B. M. ter Haar Romeny. "Retinal vessel delineation using a brain-inspired wavelet transform and random forest". In: *Pattern Recognition* 69 (2017), pp. 107–123.

[7] A. P. Mashtakov, R. Duits, Y. L. Sachkov, E. J. **Bekkers**, and I. Beschastnyi. "Tracking of Lines in Spherical Images via Sub-Riemannian Geodesics in SO(3)". In: *Journal of Mathematical Imaging and Vision* 58.2 (2017), pp. 239–264.

[8] J. Zhang, B. Dashtbozorg, E. J. **Bekkers**, J. P. W. Pluim, R. Duits, and B. M. ter Haar Romeny. "Robust Retinal Vessel Segmentation via Locally Adaptive Derivative Frames in Orientation Scores". In: *IEEE Transactions on Medical Imaging* PP.99 (2016), pp. 1–1.

[9] F. Huang, B. Dashtbozorg, J. Zhang, E. J. **Bekkers**, S. Abbasi-Sureshjani, T. Chan, and B. M. ter Haar Romeny. "Reliability of Using Retinal Vascular Fractal Dimension as a Biomarker in the Diabetic Retinopathy Detection". In: *Journal of Ophthalmology* 2016 (2016).

[10] B. M. ter Haar Romeny, E. J. **Bekkers**, J. Zhang, S. Abbasi-Sureshjani, F. Huang, R. Duits, B. Dashtbozorg, T. T. J. M. Berendschot, I. Smit-Ockeloen, K. A. J. Eppenhof, et al. "Brain-inspired algorithms for retinal image analysis". In: *Machine Vision and Applications* (2016), pp. 1–19.

[11] E. J. **Bekkers**, R. Duits, A. P. Mashtakov, and G. R. Sanguinetti. "A PDE Approach to Data-Driven Sub-Riemannian Geodesics in SE(2)". In: *SIAM Journal on Imaging Sciences* 8.4 (2015), pp. 2740–2770.

[12] E. J. **Bekkers**, R. Duits, T. T. J. M. Berendschot, and B. M. ter Haar Romeny. "A Multi-Orientation Analysis Approach to Retinal Vessel Tracking". English. In: *Journal of Mathematical Imaging and Vision* 49.3 (2014), pp. 583–610.

Conference Papers

[13] E. J. **Bekkers**, M. W. Lafarge, M. Veta, K. A. J. Eppenhof, J. P. W. Pluim, and R. Duits. "Roto-Translation Covariant Convolutional Networks for Medical Image Analysis". In: *Medical Image Computing and Computer Assisted Intervention – MICCAI 2018*. Ed. by A. F. Frangi, J. A. Schnabel, C. Davatzikos, C. Alberola-López, and G. Fichtinger. Cham: Springer International Publishing, 2018, pp. 440–448.

[14] E. J. **Bekkers**, R. Duits, A. P. Mashtakov, and Y. L. Sachkov. "Vessel Tracking via Sub-Riemannian Geodesics on the Projective Line Bundle". In: *International Conference on Geometric Science of Information*. Springer, 2017, pp. 773–781.

[15] M. H. J. Janssen, T. C. J. Dela Haije, F. C. Martin, E. J. **Bekkers**, and R. Duits. "The Hessian of axially symmetric functions on SE (3) and application in 3D image analysis". In: *International Conference on Scale Space and Variational Methods in Computer Vision*. Springer, 2017, pp. 643–655.

[16] B. Dashtbozorg, S. Abbasi-Sureshjani, J. Zhang, F. Huang, E. J. **Bekkers**, and B. M. ter Haar Romeny. "Infrastructure for Retinal Image Analysis". English. In: *Proceedings of the Ophthalmic Medical Image Analysis Third International Workshop, OMIA 2016, Held in Conjunction with MICCAI 2016, Athens, Greece, October 21, 2015*. Ed. by E. Trucco, X. Chen, M. Garvin, J. Liu, and X. Frank. Iowa Research Online, 2016, pp. 1–8.

[17] S. Abbasi-Sureshjani, I. Smit-Ockeloen, E. J. **Bekkers**, B. Dashtbozorg, and B. M. ter Haar Romeny. "Automatic detection of vascular bifurcations and crossings in retinal images using orientation scores". In: *Biomedical Imaging (ISBI), 2016 IEEE 13th International Symposium on*. IEEE, 2016, pp. 189–192.

[18] E. J. **Bekkers**, R. Duits, and M. Loog. "Training of Templates for Object Recognition in Invertible Orientation Scores: Application to Optic Nerve Head Detection in Retinal Images". English. In: *Energy Minimization Methods in Computer Vision and Pattern Recognition*. Ed. by X.-C. Tai, E. Bae, T. Chan, and M. Lysaker. Vol. 8932. Lecture Notes in Computer Science. Springer International Publishing, 2015, pp. 464–477.

[19] E. J. **Bekkers**, R. Duits, A. P. Mashtakov, and G. R. Sanguinetti. "Data-Driven Sub-Riemannian Geodesics". English. In: *Scale Space and Variational Methods in Computer Vision*. Ed. by J.-F. Aujol, M. Nikolova, and N. Papakadis. Lecture Notes in Computer Science. Springer, 2015, pp. 613–625.

[20] E. J. **Bekkers**, J. Zhang, R. Duits, and B. M. ter Haar Romeny. "Curvature Based Biomarkers for Diabetic Retinopathy via Exponential Curve Fits in SE(2)". English. In: *Proceedings of the Ophthalmic Medical Image Analysis Second International Workshop, OMIA 2015, Held in Conjunction with MICCAI 2015, Munchen, Germany, October 9, 2015*. Ed. by E. Trucco, X. Chen, M. Garvin, J. Liu, and X. Frank. Iowa Research Online, 2015, pp. 113–120.

[21] G. R. Sanguinetti, E. J. **Bekkers**, R. Duits, M. H. J. Janssen, A. P. Mashtakov, and J.-M. Mirebeau. "Sub-Riemannian Fast Marching in SE(2)". In: *Progress in Pattern Recognition, Image Analysis, Computer Vision, and Applications*. Springer International Publishing, 2015, pp. 366–374.

[22] J. Zhang, E. J. **Bekkers**, S. Abbasi-Sureshjani, B. Dashtbozorg, and B. M. ter Haar Romeny. "Robust and Fast Vessel Segmentation via Gaussian Derivatives in Orientation Scores". English. In: *International Conference on Image Analysis and Processing 2015*. Ed. by G. Vernazza, E. Puppo, and V. Murino. Lecture Notes in Computer Science. 2015, pp. 537–547.

[23] K. A. J. Eppenhof, E. J. **Bekkers**, T. T. J. M. Berendschot, J. P. W. Pluim, and B. M. ter Haar Romeny. "Retinal Artery/Vein Classifcation via Graph Cut Optimization". English. In: *Proceedings of the Ophthalmic Medical Image Analysis Second International Workshop, OMIA 2015, Held in Conjunction with MICCAI 2015, Munchen, Germany, October 9, 2015*. Ed. by E. Trucco, X. Chen, M. Garvin, J. Liu, and X. Frank. Iowa Research Online, 2015, pp. 121–128.

[24] F. Huang, J. Zhang, E. J. **Bekkers**, B. Dashtbozorg, and B. M. ter Haar Romeny. "Stability Analysis of Fractal Dimension in Retinal Vasculature". English. In: *Proceedings of the Ophthalmic Medical Image Analysis Second International Workshop, OMIA 2015, Held in Conjunction with MICCAI 2015, Munchen, Germany, October 9, 2015*. Ed. by E. Trucco, X. Chen, M. Garvin, J. Liu, and X. Frank. Iowa Research Online, 2015, pp. 1–8.

[25] J. Hannink, R. Duits, and E. J. **Bekkers**. "Crossing-Preserving Multi-scale Vesselness". English. In: *Medical Image Computing and Computer-Assisted Intervention – MICCAI 2014*. Ed. by P. Golland, N. Hata, C. Barillot, J. Hornegger, and R. Howe. Vol. 8674. Lecture Notes in Computer Science. Springer International Publishing, 2014, pp. 603–610.

[26] E. J. **Bekkers**, R. Duits, and B. M. ter Haar Romeny. "Optic Nerve Head Detection via Group Correlations in Multi-orientation Transforms". English. In: *Image Analysis and Recognition*. Ed. by A. Campilho and M. Kamel. LNCS. Springer, 2014, pp. 293–302.