



Universiteit
Leiden
The Netherlands

Fast optimization methods for image registration in adaptive radiation therapy

Qiao, Y.

Citation

Qiao, Y. (2017, November 1). *Fast optimization methods for image registration in adaptive radiation therapy*. Retrieved from <https://hdl.handle.net/1887/59448>

Version: Not Applicable (or Unknown)

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/59448>

Note: To cite this publication please use the final published version (if applicable).

Cover Page



Universiteit Leiden



The following handle holds various files of this Leiden University dissertation:

<http://hdl.handle.net/1887/59448>

Author: Qiao, Y.

Title: Fast optimization methods for image registration in adaptive radiation therapy

Issue Date: 2017-11-01

Cover Page



Universiteit Leiden



The following handle holds various files of this Leiden University dissertation:

<http://hdl.handle.net/1887/59448>

Author: Gras, S.

Title: Fast optimization methods for image registration in adaptive radiation therapy

Issue Date: 2017-11-01

Bibliography

- [1] M. A. Viergever, J. A. Maintz, S. Klein, et al. *A survey of medical image registration—under review*. 2016.
- [2] B. Zitova and J. Flusser. “Image registration methods: A survey”. In: *Image and vision computing* 21.11 (2003), pages 977–1000.
- [3] J. P. Pluim, J. A. Maintz, and M. A. Viergever. “Mutual-information-based registration of medical images: a survey”. In: *IEEE Transactions on Medical Imaging* 22.8 (2003), pages 986–1004.
- [4] S. Thörnqvist, J. B. Petersen, M. Høyer, et al. “Propagation of target and organ at risk contours in radiotherapy of prostate cancer using deformable image registration”. In: *Acta Oncologica* 49.7 (2010), pages 1023–1032.
- [5] M Zhang, D. Westerly, and T. Mackie. “Introducing an on-line adaptive procedure for prostate image guided intensity modulate proton therapy”. In: *Physics in Medicine and Biology* 56.15 (2011), page 4947.
- [6] S. Thörnqvist, L. P. Muren, L. Bentzen, et al. “Degradation of target coverage due to inter-fraction motion during intensity-modulated proton therapy of prostate and elective targets”. In: *Acta Oncologica* 52.3 (2013), pages 521–527.
- [7] A. Lomax. “Intensity modulated proton therapy and its sensitivity to treatment uncertainties 1: the potential effects of calculational uncertainties”. In: *Physics in Medicine and Biology* 53.4 (2008), page 1027.
- [8] A. Lomax. “Intensity modulated proton therapy and its sensitivity to treatment uncertainties 2: the potential effects of inter-fraction and inter-field motions”. In: *Physics in Medicine and Biology* 53.4 (2008), page 1043.
- [9] S. van de Water, H. M. Kooy, B. J. Heijmen, and M. S. Hoogeman. “Shortening delivery times of intensity modulated proton therapy by reducing proton energy layers during treatment plan optimization”. In: *International Journal of Radiation Oncology* Biology* Physics* 92.2 (2015), pages 460–468.
- [10] S. Klein, M. Staring, K. Murphy, et al. “Elastix: a toolbox for intensity-based medical image registration”. In: *IEEE Transactions on Medical Imaging* 29.1 (2010), pages 196–205.
- [11] P. Wolfe. “Convergence conditions for ascent methods”. In: *SIAM review* 11.2 (1969), pages 226–235.
- [12] H. Robbins and S. Monro. “A stochastic approximation method”. In: *Ann. Math. Statist.* 22.3 (Sept. 1951), pages 400–407.
- [13] A. Klein, J. Andersson, B. A. Ardekani, et al. “Evaluation of 14 nonlinear deformation algorithms applied to human brain MRI registration”. In: *Neuroimage* 46.3 (2009), pages 786–802.

- [14] A. Plakhov and P. Cruz. "A stochastic approximation algorithm with step-size adaptation". In: *Journal of Mathematical Sciences* 120.1 (2004), pages 964–973.
- [15] S. Klein, J. Pluim, M. Staring, and M. Viergever. "Adaptive stochastic gradient descent optimisation for image registration". English. In: *International Journal of Computer Vision* 81.3 (2009), pages 227–239.
- [16] H. J. Kushner and G. Yin. *Stochastic approximation and recursive algorithms and applications*. Volume 35. Springer Science & Business Media, 2003.
- [17] R. Suri and Y. T. Leung. "Single run optimization of a SIMAN model for closed loop flexible assembly systems". In: *Proceedings of the 19th Conference on Winter Simulation*. WSC '87. Atlanta, Georgia, USA: ACM, 1987, pages 738–748.
- [18] R. Brennan and P. Rogers. "Stochastic optimization applied to a manufacturing system operation problem". In: *Simulation Conference Proceedings, 1995. Winter*. 1995, pages 857–864.
- [19] J. Maintz and M. A. Viergever. "A survey of medical image registration". In: *Medical Image Analysis* 2.1 (1998), pages 1–36.
- [20] A. Sotiras, C. Davatzikos, and N. Paragios. "Deformable medical image registration: A survey". In: *IEEE Transactions on Medical Imaging* 32.7 (2013), pages 1153–1190.
- [21] R. Shams, P. Sadeghi, R. A. Kennedy, and R. I. Hartley. "A survey of medical image registration on multicore and the GPU". In: *IEEE Signal Processing Magazine* 27.2 (2010), pages 50–60.
- [22] D. P. Shamonin, E. E. Bron, B. P. Lelieveldt, et al. "Fast parallel image registration on CPU and GPU for diagnostic classification of Alzheimer's disease". In: *Frontiers in Neuroinformatics* 7 (2014), page 50.
- [23] F. Maes, D. Vandermeulen, and P. Suetens. "Comparative evaluation of multiresolution optimization strategies for multimodality image registration by maximization of mutual information". In: *Medical Image Analysis* 3.4 (1999), pages 373–386.
- [24] J. Kybic and M. Unser. "Fast parametric elastic image registration". In: *IEEE Transactions on Image Processing* 12.11 (2003), pages 1427–1442.
- [25] S. Klein, M. Staring, and J. P. Pluim. "Evaluation of optimization methods for non-rigid medical image registration using mutual information and B-splines". In: *IEEE Transactions on Image Processing* 16.12 (2007), pages 2879–2890.
- [26] R. C. Hardie, K. J. Barnard, and E. E. Armstrong. "Joint MAP registration and high-resolution image estimation using a sequence of undersampled images". In: *IEEE Transactions on Image Processing* 6.12 (1997), pages 1621–1633.
- [27] P. Thevenaz and M. Unser. "Optimization of mutual information for multiresolution image registration". In: *IEEE Transactions on Image Processing* 9.12 (2000), pages 2083–2099.
- [28] S. Kabus, T. Netsch, B. Fischer, and J. Modersitzki. "B-spline registration of 3D images with Levenberg-Marquardt optimization". In: *Medical Imaging 2004*. International Society for Optics and Photonics. 2004, pages 304–313.
- [29] M. Kisaki, Y. Yamamura, H. Kim, et al. "High speed image registration of head CT and MR images based on Levenberg-Marquardt algorithms". In: *Soft Computing and Intelligent Systems (SCIS), 2014 Joint 7th International Conference on and Advanced Intelligent Systems (ISIS), 15th International Symposium on*. IEEE. 2014, pages 1481–1485.

- [30] D. Mattes, D. R. Haynor, H. Vesselle, et al. "PET-CT image registration in the chest using free-form deformations". In: *IEEE Transactions on Medical Imaging* 22.1 (2003), pages 120–128.
- [31] M. Sdika. "A fast nonrigid image registration with constraints on the Jacobian using large scale constrained optimization". In: *IEEE Transactions on Medical Imaging* 27.2 (2008), pages 271–281.
- [32] S. Damas, O. Cordón, and J. Santamaría. "Medical imager registration using evolutionary computation: An experimental survey". In: *IEEE Computational Intelligence Magazine* 6.4 (2011), pages 26–42.
- [33] M. P. Wachowiak, R. Smolíková, Y. Zheng, et al. "An approach to multimodal biomedical image registration utilizing particle swarm optimization". In: *IEEE Transactions on Evolutionary Computation* 8.3 (2004), pages 289–301.
- [34] Y.-W. Chen, C.-L. Lin, and A. Mimori. "Multimodal medical image registration using particle swarm optimization". In: *Intelligent Systems Design and Applications, 2008. ISDA'08. Eighth International Conference on*. Volume 3. IEEE. 2008, pages 127–131.
- [35] A. A. Cole-Rhodes, K. L. Johnson, J. LeMoigne, and I. Zavorin. "Multiresolution registration of remote sensing imagery by optimization of mutual information using a stochastic gradient". In: *IEEE Transactions on Image Processing* 12.12 (2003), pages 1495–1511.
- [36] J. C. Spall. "Implementation of the simultaneous perturbation algorithm for stochastic optimization". In: *IEEE Transactions on Aerospace and Electronic Systems* 34.3 (1998), pages 817–823.
- [37] L. Bottou. "Stochastic gradient learning in neural networks". In: *Proceedings of Neuro-Nimes* 91.8 (1991).
- [38] A Harju, B Barbiellini, S Siljamäki, et al. "Stochastic gradient approximation: An efficient method to optimize many-body wave functions". In: *Physical Review Letters* 79.7 (1997), page 1173.
- [39] H. Kesten. "Accelerated stochastic approximation". In: *The Annals of Mathematical Statistics* (1958), pages 41–59.
- [40] A Gaivoronski. *Stochastic quasigradient methods and their implementation*. 1988.
- [41] Y.-H. Dai and H. Zhang. "Adaptive two-point stepsize gradient algorithm". In: *Numerical Algorithms* 27.4 (2001), pages 377–385.
- [42] J. C. Spall. *Introduction to stochastic search and optimization: estimation, simulation, and control*. Volume 65. John Wiley & Sons, 2005.
- [43] A. P. George and W. B. Powell. "Adaptive stepsizes for recursive estimation with applications in approximate dynamic programming". In: *Machine Learning* 65.1 (2006), pages 167–198.
- [44] R. Bhagalia, J. A. Fessler, and B. Kim. "Accelerated nonrigid intensity-based image registration using importance sampling". In: *IEEE Transactions on Medical Imaging* 28.8 (2009), pages 1208–1216.
- [45] Y Qiao, B. Lelieveldt, and M Staring. "Fast automatic estimation of the optimization step size for nonrigid image registration". In: *SPIE Medical Imaging*. International Society for Optics and Photonics. 2014, 90341A–90341A.
- [46] D. Vysochanskij and Y. I. Petunin. "Justification of the 3σ rule for unimodal distributions". In: *Theory of Probability and Mathematical Statistics* 21 (1980), pages 25–36.

- [47] J. West, J. M. Fitzpatrick, M. Y. Wang, et al. "Comparison and evaluation of retrospective intermodality brain image registration techniques". In: *Journal of Computer Assisted Tomography* 21.4 (1997), pages 554–568.
- [48] J. Stolk, H. Putter, E. M. Bakker, et al. "Progression parameters for emphysema: a clinical investigation". In: *Respiratory Medicine* 101.9 (2007), pages 1924–1930.
- [49] K. Murphy, B. van Ginneken, S. Klein, et al. "Semi-automatic construction of reference standards for evaluation of image registration". In: *Medical Image Analysis* 15.1 (2011), pages 71–84.
- [50] M. Staring, M. Bakker, J Stolk, et al. "Towards local progression estimation of pulmonary emphysema using CT". In: *Medical physics* 41.2 (2014), page 021905.
- [51] A. Hammers, R. Allom, M. J. Koepp, et al. "Three-dimensional maximum probability atlas of the human brain, with particular reference to the temporal lobe". In: *Human Brain Mapping* 19.4 (2003), pages 224–247.
- [52] I. S. Gousias, D. Rueckert, R. A. Heckemann, et al. "Automatic segmentation of brain MRIs of 2-year-olds into 83 regions of interest". In: *NeuroImage* 40.2 (2008), pages 672–684.
- [53] S. Vijayan, S. Klein, E. F. Hofstad, et al. "Motion tracking in the liver: Validation of a method based on 4D ultrasound using a nonrigid registration technique". In: *Medical physics* 41.8 (2014).
- [54] P. Seroul and D. Sarrut. "VV: a viewer for the evaluation of 4D image registration". In: *MIDAS Journal (Medical Image Computing and Computer-Assisted Intervention MICCAI 2008, Workshop-Systems and Architectures for Computer Assisted Interventions)*. 2008, pages 1–8.
- [55] F. Maes, A. Collignon, D. Vandermeulen, et al. "Multimodality image registration by maximization of mutual information". In: *IEEE Transactions on Medical Imaging* 16.2 (1997), pages 187–198.
- [56] *Life Science Grid*. URL: <https://surfsara.nl/project/life-science-grid> (visited on 08/21/2014).
- [57] D. Rueckert, L. I. Sonoda, C. Hayes, et al. "Nonrigid registration using free-form deformations: application to breast MR images". In: *IEEE Transactions on Medical Imaging* 18.8 (1999), pages 712–721.
- [58] C. Metz, S. Klein, M. Schaap, et al. "Nonrigid registration of dynamic medical imaging data using nD+ t B-splines and a groupwise optimization approach". In: *Medical Image Analysis* 15.2 (2011), pages 238–249.
- [59] W. Sun, W. Niessen, M. van Stralen, and S. Klein. "Simultaneous multiresolution strategies for nonrigid image registration". In: *IEEE Transactions on Image Processing* 22.12 (2013), pages 4905–4917.
- [60] N. N. Schraudolph and T. Graepel. "Combining conjugate direction methods with stochastic approximation of gradients". In: *Proceedings of the Ninth International Workshop on Artificial Intelligence and Statistics, AISTATS 2003*. 2003.
- [61] E. Laure, A. Edlund, F. Pacini, et al. *Programming the Grid with gLite*. Mar. 2006. URL: <http://cds.cern.ch/record/936685> (visited on 08/21/2014).
- [62] P. Andreetto, S. Andreozzi, G. Avellino, et al. "The gLite workload management system". en. In: *Journal of Physics: Conference Series* 119.6 (July 2008), page 062007. URL: <http://iopscience.iop.org/1742-6596/119/6/062007> (visited on 08/21/2014).

- [63] *EGI site*. URL: <http://www.egi.eu/> (visited on 08/21/2014).
- [64] C. Marco, C. Fabio, D. Alvise, et al. "The gLite workload management system". en. In: *Advances in Grid and Pervasive Computing*. Edited by N. Abdennadher and D. Petcu. Lecture Notes in Computer Science 5529. Springer Berlin Heidelberg, Jan. 2009, pages 256–268. URL: http://link.springer.com/chapter/10.1007/978-3-642-01671-4_24 (visited on 08/21/2014).
- [65] A. Casajus, R. Graciani, S. Paterson, et al. "DIRAC pilot framework and the DIRAC workload management system". en. In: *Journal of Physics: Conference Series* 219.6 (Apr. 2010), page 062049. URL: <http://iopscience.iop.org/1742-6596/219/6/062049> (visited on 08/21/2014).
- [66] *jjbot/picasclient*. URL: <https://github.com/jjbot/picasclient> (visited on 08/21/2014).
- [67] *RP3 / Grid training | GitLab*. URL: https://git.lumc.nl/rp3/grid_training/tree/1c654deb90d85a4c62cbc1cfac6f2fb64572a78b (visited on 08/21/2014).
- [68] *Welcome to*. URL: <https://www.python.org/> (visited on 08/21/2014).
- [69] *Ganga: Gaudi/Athena and Grid Alliance*. URL: <http://ganga.web.cern.ch/ganga/> (visited on 08/21/2014).
- [70] S. Klein, M. Staring, et al. "Preconditioned stochastic gradient descent optimisation for monomodal image registration". In: *Medical Image Computing and Computer-Assisted Intervention—MICCAI 2011*. Springer, 2011, pages 549–556.
- [71] N. N. Schraudolph, J. Yu, S. Günter, et al. "A stochastic quasi-Newton method for online convex optimization." In: *AISTATS*. Volume 7. 2007, pages 436–443.
- [72] A. Bordes, L. Bottou, and P. Gallinari. "SGD-QN: careful quasi-Newton stochastic gradient descent". In: *The Journal of Machine Learning Research* 10 (2009), pages 1737–1754.
- [73] A. Mokhtari and A. Ribeiro. "RES: Regularized stochastic BFGS algorithm". In: *Signal Processing, IEEE Transactions on* 62.23 (2014), pages 6089–6104.
- [74] R. H. Byrd, S. Hansen, J. Nocedal, and Y. Singer. "A stochastic Quasi-Newton method for large-scale optimization". In: *arXiv preprint arXiv:1401.7020* (2014).
- [75] B. O' Donoghue and E. Candès. "Adaptive restart for accelerated gradient schemes". English. In: *Foundations of Computational Mathematics* (2013), pages 1–18.
- [76] J. Kiefer and J. Wolfowitz. "Stochastic estimation of the maximum of a regression function". In: *The Annals of Mathematical Statistics* 23.3 (1952), pages 462–466.
- [77] J. Stolk, H. Putter, E. M. Bakker, et al. "Progression parameters for emphysema: a clinical investigation". In: *Respiratory medicine* 101.9 (2007), pages 1924–1930.
- [78] F. Modarres Khiyabani and W. Leong. "Limited memory methods with improved symmetric rank-one updates and its applications on nonlinear image restoration". English. In: *Arabian Journal for Science and Engineering* 39.11 (2014), pages 7823–7838.
- [79] J. Nocedal and S. J. Wright. "Numerical optimization, second edition". In: *Numerical optimization* (2006), pages 497–528.
- [80] V. Cevher, S. Becker, and M. Schmidt. "Convex optimization for big data: Scalable, randomized, and parallel algorithms for big data analytics". In: *Signal Processing Magazine, IEEE* 31.5 (2014), pages 32–43.
- [81] R. Szeliski and J. Coughlan. "Spline-based image registration". In: *International Journal of Computer Vision* 22.3 (1997), pages 199–218.

- [82] Y. Saad and H. A. Van Der Vorst. "Iterative solution of linear systems in the 20th century". In: *Journal of Computational and Applied Mathematics* 123.1 (2000), pages 1–33.
- [83] M. Benzi. "Preconditioning techniques for large linear systems: a survey". In: *Journal of computational Physics* 182.2 (2002), pages 418–477.
- [84] A. V. Knyazev and I. Lashuk. "Steepest descent and conjugate gradient methods with variable preconditioning". In: *SIAM Journal on Matrix Analysis and Applications* 29.4 (2007), pages 1267–1280.
- [85] C. Li, C. Chen, D. Carlson, and L. Carin. "Preconditioned stochastic gradient Langevin dynamics for deep neural networks". In: *Thirtieth AAAI Conference on Artificial Intelligence*. 2016.
- [86] H. Jiang, G. Huang, P. A. Wilford, and L. Yu. "Constrained and preconditioned stochastic gradient method". In: *IEEE Transactions on Signal Processing* 63.10 (2015), pages 2678–2691.
- [87] D. E. Carlson, E. Collins, Y.-P. Hsieh, et al. "Preconditioned spectral descent for deep learning". In: *Advances in Neural Information Processing Systems*. 2015, pages 2971–2979.
- [88] Y. Dauphin, H. de Vries, and Y. Bengio. "Equilibrated adaptive learning rates for non-convex optimization". In: *Advances in Neural Information Processing Systems*. 2015, pages 1504–1512.
- [89] D. Zikic, M. Baust, A. Kamen, and N. Navab. "A general preconditioning scheme for difference measures in deformable registration". In: *Computer Vision (ICCV), 2011 IEEE International Conference on*. IEEE. 2011, pages 49–56.
- [90] J. L. Morales and J. Nocedal. "Automatic preconditioning by limited memory quasi-Newton updating". In: *SIAM Journal on Optimization* 10.4 (2000), pages 1079–1096.
- [91] T. P. Minka. "A comparison of numerical optimizers for logistic regression". In: *Unpublished draft* (2003).
- [92] J. Ngiam, A. Coates, A. Lahiri, et al. "On optimization methods for deep learning". In: *Proceedings of the 28th International Conference on Machine Learning (ICML-11)*. 2011, pages 265–272.
- [93] J. Yu, S. Vishwanathan, S. Günter, and N. N. Schraudolph. "A quasi-Newton approach to nonsmooth convex optimization problems in machine learning". In: *Journal of Machine Learning Research* 11.Mar (2010), pages 1145–1200.
- [94] R. H. Byrd, S. L. Hansen, J. Nocedal, and Y. Singer. "A stochastic quasi-Newton method for large-scale optimization". In: *SIAM Journal on Optimization* 26.2 (2016), pages 1008–1031.
- [95] F. Maes, D. Vandermeulen, and P. Suetens. "Comparative evaluation of multiresolution optimization strategies for multimodality image registration by maximization of mutual information". In: *Medical Image Analysis* 3.4 (1999), pages 373–386.
- [96] D. Mattes, D. R. Haynor, H. Vesselle, et al. "PET-CT image registration in the chest using free-form deformations". In: *IEEE transactions on medical imaging* 22.1 (2003), pages 120–128.
- [97] Y. Qiao, Z. Sun, B. P. Lelieveldt, and M. Staring. "A stochastic quasi-Newton method for non-rigid image registration". In: *International Conference on Medical Image Computing and Computer-Assisted Intervention*. Springer International Publishing. 2015, pages 297–304.

- [98] W. Li, D. A. Jaffray, G. Wilson, and D. Moseley. "How long does it take? An analysis of volumetric image assessment time". In: *Radiotherapy and Oncology* 119.1 (2016), pages 150–153.
- [99] T. N. Sainath, L. Horesh, B. Kingsbury, et al. "Accelerating Hessian-free optimization for deep neural networks by implicit preconditioning and sampling". In: *Automatic Speech Recognition and Understanding (ASRU), 2013 IEEE Workshop on*. IEEE. 2013, pages 303–308.
- [100] Y. Qiao, B. van Lew, B. P. Lelieveldt, and M. Staring. "Fast automatic step size estimation for gradient descent optimization of image registration". In: *IEEE Transactions on Medical Imaging* 35.2 (2016), pages 391–403.
- [101] C. A. Cocosco, V. Kollokian, R. K.-S. Kwan, et al. "Brainweb: Online interface to a 3D MRI simulated brain database". In: *NeuroImage*. Citeseer. 1997.
- [102] S. M. Smith. "Fast robust automated brain extraction". In: *Human Brain Mapping* 17.3 (2002), pages 143–155.
- [103] W. Sun, D. H. Poot, I. Smal, et al. "Stochastic optimization with randomized smoothing for image registration". In: *Medical Image Analysis* 35 (2017), pages 146–158.
- [104] P. Castadot, J. A. Lee, A. Parraga, et al. "Comparison of 12 deformable registration strategies in adaptive radiation therapy for the treatment of head and neck tumors". In: *Radiotherapy and Oncology* 89.1 (2008), pages 1–12.
- [105] A. Kumarasiri, F. Siddiqui, C. Liu, et al. "Deformable image registration based automatic CT-to-CT contour propagation for head and neck adaptive radiotherapy in the routine clinical setting". In: *Medical Physics* 41.12 (2014), page 121712.
- [106] J. A. Shackleford, N. Kandasamy, and G. Sharp. "On developing B-spline registration algorithms for multi-core processors". In: *Physics in Medicine and Biology* 55.21 (2010), page 6329.
- [107] D. Yang, S. Brame, I. El Naqa, et al. "Technical Note: DIRART—A software suite for deformable image registration and adaptive radiotherapy research". In: *Medical Physics* 38.1 (2011), pages 67–77.
- [108] D. C. Ince, L. Hatton, and J. Graham-Cumming. "The case for open computer programs". In: *Nature* 482.7386 (2012), pages 485–488.
- [109] B. C. Lowekamp, D. T. Chen, L. Ibáñez, and D. Blezek. "The design of SimpleITK". In: *Frontiers in Neuroinformatics* 7.45 (2013).
- [110] M. Thor, E. S. Andersen, J. B. Petersen, et al. "Evaluation of an application for intensity-based deformable image registration and dose accumulation in radiotherapy". In: *Acta Oncologica* 53.10 (2014), pages 1329–1336.
- [111] G. Cazoulat, A. Simon, A. Dumenil, et al. "Surface-constrained nonrigid registration for dose monitoring in prostate cancer radiotherapy". In: *IEEE Transactions on Medical Imaging* 33.7 (2014), pages 1464–1474.
- [112] M. Nassef, A. Simon, G. Cazoulat, et al. "Quantification of dose uncertainties in cumulated dose estimation compared to planned dose in prostate IMRT". In: *Radiotherapy and Oncology* 119.1 (2016), pages 129–136.
- [113] T. Zhang, Y. Chi, E. Meldolesi, and D. Yan. "Automatic delineation of on-line head-and-neck computed tomography images: toward on-line adaptive radiotherapy". In: *International Journal of Radiation Oncology* Biology* Physics* 68.2 (2007), pages 522–530.

- [114] G. Landry, R. Nijhuis, G. Dedes, et al. "Investigating CT to CBCT image registration for head and neck proton therapy as a tool for daily dose recalculation". In: *Medical Physics* 42.3 (2015), pages 1354–1366.
- [115] P. Castadot, X. Geets, J. A. Lee, et al. "Assessment by a deformable registration method of the volumetric and positional changes of target volumes and organs at risk in pharyngolaryngeal tumors treated with concomitant chemo-radiation". In: *Radiotherapy and Oncology* 95.2 (2010), pages 209–217.
- [116] P. Kupelian, T. Willoughby, A. Mahadevan, et al. "Multi-institutional clinical experience with the Calypso system in localization and continuous, real-time monitoring of the prostate gland during external radiotherapy". In: *International Journal of Radiation Oncology* Biology* Physics* 67.4 (2007), pages 1088–1098.
- [117] H. Ariyaratne, H. Chesham, J. Pettingell, and R. Alonzi. "Image-guided radiotherapy for prostate cancer with cone beam CT: dosimetric effects of imaging frequency and PTV margin". In: *Radiotherapy and Oncology* 121.1 (2016), pages 103–108.
- [118] A. Godley, E. Ahunbay, C. Peng, and X. A. Li. "Automated registration of large deformations for adaptive radiation therapy of prostate cancer". In: *Medical Physics* 36.4 (2009), pages 1433–1441.
- [119] D. Robb, A. Plank, and M. Middleton. "Assessing the efficiency and consistency of daily image-guided radiation therapy in a modern radiotherapy centre". In: *Journal of Medical Imaging and Radiation Sciences* 45.2 (2014), pages 72–78.
- [120] G. Sharp, N Kandasamy, H Singh, and M. Folkert. "GPU-based streaming architectures for fast cone-beam CT image reconstruction and Demons deformable registration". In: *Physics in Medicine and Biology* 52.19 (2007), page 5771.
- [121] L. P. Muren, E. Wasbø, S. I. Helle, et al. "Intensity-modulated radiotherapy of pelvic lymph nodes in locally advanced prostate cancer: planning procedures and early experiences". In: *International Journal of Radiation Oncology* Biology* Physics* 71.4 (2008), pages 1034–1041.
- [122] W. Huizinga, S. Klein, and D. H. Poot. "Fast multidimensional B-spline interpolation using template metaprogramming". In: *Biomedical Image Registration*. Springer, 2014, pages 11–20.
- [123] P. Thevenaz and M. Unser. "Optimization of mutual information for multiresolution image registration". In: *IEEE Transactions on Image Processing* 9.12 (2000), pages 2083–2099.
- [124] C. Lu, S. Chelikani, X. Papademetris, et al. "An integrated approach to segmentation and nonrigid registration for application in image-guided pelvic radiotherapy". In: *Medical Image Analysis* 15.5 (2011), pages 772–785.
- [125] S. Breedveld, P. R. Storch, P. W. Voet, and B. J. Heijmen. "iCycle: Integrated, multicriterial beam angle, and profile optimization for generation of coplanar and noncoplanar IMRT plans". In: *Medical Physics* 39.2 (2012), pages 951–963.
- [126] S. van de Water, A. Kraan, S. Breedveld, et al. "Improved efficiency of multi-criteria IMPT treatment planning using iterative resampling of randomly placed pencil beams". In: *Physics in Medicine and Biology* 58.19 (2013), page 6969.
- [127] M Moteabbed, A Trofimov, G. Sharp, et al. "Proton therapy of prostate cancer by anterior-oblique beams: implications of setup and anatomy variations". In: *Physics in Medicine and Biology* 62.5 (2017), page 1644.

- [128] S. Thörnqvist, L. Bentzen, J. B. Petersen, et al. “Plan robustness of simultaneous integrated boost radiotherapy of prostate and lymph nodes for different image-guidance and delivery techniques”. In: *Acta Oncologica* 50.6 (2011), pages 926–934.
- [129] L. Bondar, M. Hoogeman, J. W. Mens, et al. “Toward an individualized target motion management for IMRT of cervical cancer based on model-predicted cervix–uterus shape and position”. In: *Radiotherapy and Oncology* 99.2 (2011), pages 240–245.
- [130] A. Qin, Y. Sun, J. Liang, and D. Yan. “Evaluation of online/offline image guidance/adaptation approaches for prostate cancer radiation therapy”. In: *International Journal of Radiation Oncology* Biology* Physics* 91.5 (2015), pages 1026–1033.
- [131] G. Gunay, L. M. Ha, T. van Walsum, and S. Klein. “Semi-automated registration of pre- and intra-operative liver CT for image-guided interventions”. In: *SPIE Medical Imaging*. International Society for Optics and Photonics. 2016, 97841N–97841N.
- [132] S. Gao, L. Zhang, H. Wang, et al. “A deformable image registration method to handle distended rectums in prostate cancer radiotherapy”. In: *Medical physics* 33.9 (2006), pages 3304–3312.
- [133] G. Saygili, M. Staring, and E. A. Hendriks. “Confidence estimation for medical image registration based on stereo confidences”. In: *IEEE Transactions on Medical Imaging* 35.2 (2016), pages 539–549.
- [134] H. Sokooti, G. Saygili, B. Glocker, et al. “Accuracy Estimation for Medical Image Registration Using Regression Forests”. In: *International Conference on Medical Image Computing and Computer-Assisted Intervention*. Springer. 2016, pages 107–115.
- [135] K. H. Cha, L. Hadjiiski, R. K. Samala, et al. “Urinary bladder segmentation in CT urography using deep-learning convolutional neural network and level sets”. In: *Medical physics* 43.4 (2016), pages 1882–1896.
- [136] C. Veiga, G. Janssens, C.-L. Teng, et al. “First clinical investigation of cone beam computed tomography and deformable registration for adaptive proton therapy for lung cancer”. In: *International Journal of Radiation Oncology* Biology* Physics* 95.1 (2016), pages 549–559.
- [137] W. Sun, D. H. Poot, I. Smal, et al. “Stochastic optimization with randomized smoothing for image registration”. In: *Medical Image Analysis* 35 (2017), pages 146–158.
- [138] J. Duchi, E. Hazan, and Y. Singer. “Adaptive subgradient methods for online learning and stochastic optimization”. In: *Journal of Machine Learning Research* 12.Jul (2011), pages 2121–2159.
- [139] M. D. Zeiler. “ADADELTA: An adaptive learning rate method”. In: *CoRR* abs/1212.5701 (2012). URL: <http://arxiv.org/abs/1212.5701>.
- [140] D. Kingma and J. Ba. “Adam: A method for stochastic optimization”. In: *arXiv preprint arXiv:1412.6980* (2014).
- [141] N. N. Schraudolph and T. Graepel. “Conjugate directions for stochastic gradient descent”. In: *International Conference on Artificial Neural Networks*. Springer. 2002, pages 1351–1356.
- [142] R. Johnson and T. Zhang. “Accelerating stochastic gradient descent using predictive variance reduction”. In: *Advances in Neural Information Processing Systems*. 2013, pages 315–323.
- [143] Y. Nesterov. “A method for unconstrained convex minimization problem with the rate of convergence $O(1/k^2)$ ”. In: *Doklady an SSSR*. Volume 269. 3. 1983, pages 543–547.

- [144] N. Qian. “On the momentum term in gradient descent learning algorithms”. In: *Neural networks* 12.1 (1999), pages 145–151.
- [145] Y. Liu, R. Jin, M. Chen, et al. “Contour propagation using non-uniform cubic B-splines for lung tumor delineation in 4D-CT”. In: *International journal of computer assisted radiology and surgery* 11.12 (2016), pages 2139–2151.
- [146] W. Sun, W. J. Niessen, and S. Klein. “Randomly perturbed B-splines for nonrigid image registration”. In: *IEEE Transactions on Pattern Analysis and Machine Intelligence* PP.99 (2016), pages 1–1.
- [147] J. Kallwies, T. Engler, and H.-J. Wuensche. “A fast and accurate image-registration algorithm using prior knowledge”. In: *Digital Image Computing: Techniques and Applications (DICTA), 2016 International Conference on*. IEEE. 2016, pages 1–8.