

## Andrea Censi

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### EMPLOYMENT



**ETH Zürich** – Zürich, Switzerland  
*Oberassistent* (Senior Research Scientist)  
Institute for Dynamic Systems and Control, in E. Frazzoli's group.

02/2017 –



**nuTonomy, inc** – Cambridge, MA, USA and Singapore  
System Architect

03/2017 –



**Duckietown Engineering**  
Chief Technology Officer

01/2016 –



**Massachusetts Institute of Technology**, Cambridge, MA, USA.  
Research Scientist, Principal Investigator  
Laboratory for Information and Decision Systems

10/2013 – 04/2017

I have also held visiting positions. In 2012-13 I was Visiting Scholar at the AI Lab in D. Scaramuzza's group. In 2005 I was a visiting student at the Tokyo Institute of Technology, in Hirose lab.

### EDUCATION



**California Institute of Technology**, Pasadena, CA, USA.  
Ph.D. in Control & Dynamical Systems  
Thesis: *Bootstrapping Vehicles: a Formal Approach to Unsupervised Learning of Robotic Sensorimotor Cascades Based on Invariance* [12]  
Advisor: **Richard M. Murray**

9/2007 – 6/2012



**Università di Roma "La Sapienza"**, Rome, Italy.  
*Laurea magistrale* (M.Sc.) in Control Engineering & Robotics, *cum laude*  
Thesis: *Robot Motion Planning with Uncertainty* [41]  
Advisors: **G. Oriolo, A. De Luca**.  
*Laurea* (B.Sc.) in Automation & Control Engineering, *cum laude*  
Thesis: *Scan Matching in the Hough Domain* [48] (advisor: **D. Nardi**)

5/2005 – 5/2007

9/2001 – 5/2005

### GRANTS AND AWARDS

- I have been the recipient as PI or co-PI of NSF, DARPA, and AFRL awards.
- Best conference paper finalist [31] at ICRA 2011. Best student paper finalist [28] at ICRA 2012.

### PROFESSIONAL SERVICE

- Reviewer/PC member for conferences/journals in robotics (TRO, IJRR, ICRA, IROS, RSS) and control (TAC, TSP, Automatica, CDC, ACC). Associate Editor for ICRA.
- ICRA 2016 Publicity Chair and **duckie dealer**.
- **ICRA 2015 Trailer** organizer and director.
- Co-organizer with Soatto (UCLA), Tsiotras (GATECH) of ICRA 2016 workshop on "Task-driven representations".
- Co-organizer with Scaramuzza (UZH) of ICRA 2015 workshop on "Innovative Sensing for Robotics".
- Co-organizer with Boots (GATECH) of ICRA 2015 workshop on "Advances in Sensorimotor Learning".
- Co-organizer with Frazzoli, Leonard of **RSS 2015 workshop on "The Big Questions in Robotics"**.
- NSF Panelist (2015)

## SOFTWARE PRODUCTS



- Robotics software: *CSM* [42, 45]: extremely fast laser scan matching - part of ROS as `laser_scan_matcher`. Currently deployed and maintained by Kuka.
- Scientific computing software: *PyContracts*: contracts checking for Python; *Compmake*: minimal effort parallelization for Python applications—<http://compmake.org>

## SELECTED PUBLICATIONS



















Legend:  link to pdf;  link to slides;  link to website with source code and datasets.

### Preprints / working papers




(any feedback on preprints is much appreciated)

- [1] A. Censi. *A Mathematical Theory of Co-Design*. Tech. rep. Laboratory for Information and Decision Systems, MIT, Sept. 2016  .

### Journal Papers

- [2] A. Censi. “Uncertainty in Monotone Co-Design Problems”. In: *IEEE Robotics and Automation Letters* (2017)  .
- [3] A. Censi. “A Class of Co-Design Problems With Cyclic Constraints and Their Solution”. In: *IEEE Robotics and Automation Letters* 2.1 (2016). Superseded by preprint “A Mathematical Theory of Co-Design”, pp. 96–103. ISSN: 2377-3766 DOI:10.1109/LRA.2016.2535127.
- [4] A. Censi and R. M. Murray. “Bootstrapping bilinear models of Simple Vehicles”. In: *International Journal of Robotics Research* 34 (July 2015), pp. 1087–1113 DOI:10.1177/0278364914557708   .
- [5] S. B. Fuller, M. Karpelson, A. Censi, K. Y. Ma, and R. J. Wood. “Controlling free flight of a robotic fly using an onboard vision sensor inspired by insect ocelli”. In: *Journal of the Royal Society Interface* 97 (Aug. 2014) .
- [6] L. Carlone and A. Censi. “From Angular Manifolds to the Integer Lattice: Guaranteed Orientation Estimation with Application to Pose Graph Optimization”. In: *IEEE Transactions on Robotics* 30.4 (Apr. 2014) DOI:10.1109/TRO.2013.2291626   .
- [7] A. Censi\*, A. D. Straw\*, R. W. Sayaman, R. M. Murray, and M. H. Dickinson. “Discriminating external and internal causes for saccade initiation in freely flying *Drosophila*”. In: *PLOS Computational Biology* 9.2 (Feb. 2013) DOI:10.1371/journal.pcbi.1002891   .
- [8] A. Censi and D. Scaramuzza. “Calibration by correlation using metric embedding from non-metric similarities”. In: *IEEE Transactions on Pattern Analysis and Machine Intelligence* 35 (10 Oct. 2013), pp. 2357–2370 DOI:10.1109/TPAMI.2013.34  .
- [9] A. Censi, A. Franchi, L. Marchionni, and G. Oriolo. “Simultaneous calibration of odometry and sensor parameters for mobile robots”. In: *IEEE Transactions on Robotics* 29.2 (Apr. 2013), pp. 475–492 DOI:10.1109/TRO.2012.2226380  .
- [10] D. Calisi, A. Censi, L. Iocchi, and D. Nardi. “Design choices for modular and flexible robotic software development: the OpenRDK viewpoint”. In: *Journal of Software Engineering for Robotics* 1 (3 Mar. 2012) .
- [11] A. Censi. “Kalman filtering with intermittent observations: convergence for semi-Markov chains and an intrinsic performance measure”. In: *IEEE Transactions on Automatic Control* (Feb. 2011). ISSN: 0018-9286 DOI:10.1109/TAC.2010.2097350 .










### Dissertation

- [12] A. Censi. *Bootstrapping Vehicles: A Formal Approach to Unsupervised Sensorimotor Learning Based on Invariance*. Tech. rep. California Institute of Technology, 2012   .

### Conference Papers

- [13] L. Paull et al. “Duckietown: an Open and Inexpensive and Flexible Platform for Autonomy Education and Research”. In: *IEEE International Conference on Robotics and Automation (ICRA)*. Singapore, May 2017  .
- [14] J. Tani, L. Paull, M. Zuber, D. Rus, J. How, J. Leonard, and A. Censi. “Duckietown: an Innovative Way to Teach Autonomy”. In: *EduRobotics 2016*. Athens, Greece, Dec. 2016  .
- [15] A. Censi. “Monotone Co-Design Problems; or, everything is the same”. In: *Proceedings of the American Control Conference (ACC)*. Superseded by preprint “A Mathematical Theory of Co-Design”, 2016 DOI:10.1109/ACC.2016.7525085.
- [16] E. Mueller, A. Censi, and E. Frazzoli. “Efficient high speed signal estimation with neuromorphic vision sensors”. In: *International Conference on Event-based Control, Communication, and Signal Processing (EBCCSP)*. 2015, pp. 1–8 DOI:10.1109/EBCCSP.2015.7300672.
- [17] E. Mueller, A. Censi, and E. Frazzoli. “Low-latency heading feedback control with neuromorphic vision sensors using efficient approximated incremental inference”. In: *IEEE Conference on Decision and Control (CDC)*. 2015, pp. 992–999 DOI:10.1109/CDC.2015.7402002.
- [18] P. Singh, S. Z. Yong, J. Gregoire, A. Censi, and E. Frazzoli. “Stabilization of linear continuous-time systems using neuromorphic vision sensors”. In: *IEEE Conference on Decision and Control (CDC)*. 2016, pp. 3030–3036 DOI:10.1109/CDC.2016.7798722.
- [19] A. Censi. “Efficient Neuromorphic Optomotor Heading Regulation”. In: *American Control Conference (ACC)*. Chicago, IL, July 2015 DOI:10.1109/ACC.2015.7171931.
- [20] A. Censi, E. Mueller, E. Frazzoli, and S. Soatto. “A Power-Performance Approach to Comparing Sensor Families, with application to comparing neuromorphic to traditional vision sensors”. In: *IEEE International Conference on Robotics and Automation (ICRA)*. May 2015.

- [21] L. Carlone, A. Censi, and F. Dellaert. “Coherent Measurements Selection via l1 Relaxation: an Approach to Robust Estimation over Graphs”. In: *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. Oct. 2014.
- [22] A. Censi and D. Scaramuzza. “Low-latency Event-Based Visual Odometry”. In: *IEEE International Conference on Robotics and Automation (ICRA)*. May 2014   .
- [23] A. Censi, J. Strubel, C. Brandli, T. Delbruck, and D. Scaramuzza. “Low-latency localization by Active LED Markers tracking using a Dynamic Vision Sensor”. In: *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. Tokyo, Japan, Nov. 2013, pp. 891–898 DOI:10.1109/IROS.2013.6696456   .
- [24] A. Nilsson and A. Censi. “Accurate recursive learning of uncertain diffeomorphism dynamics”. In: *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. Tokyo, Japan, Nov. 2013 DOI:10.1109/IROS.2013.6696504  .
- [25] A. Censi, A. Nilsson, and R. M. Murray. “Motion planning in observations space with learned diffeomorphism models.” In: *Proceedings of the IEEE International Conference on Robotics and Automation (ICRA)*. Karlsruhe, Germany, May 2013, pp. 2860–2867 DOI:10.1109/ICRA.2013.6630973  .
- [26] P. Puente and A. Censi. “Dense Map Inference with User-Defined Priors: From Priorlets to Scan Eigenvariations”. In: *Spatial Cognition VIII*. Ed. by C. Stachniss, K. Schill, and D. Uttal. Vol. 7463. Lecture Notes in Computer Science. Springer Berlin Heidelberg, Aug. 2012, pp. 94–113. ISBN: 978-3-642-32731-5 DOI:10.1007/978-3-642-32732-2\_6  .
- [27] A. Censi and R. M. Murray. “Learning diffeomorphism models of robotic sensorimotor cascades”. In: *Proceedings of the IEEE International Conference on Robotics and Automation (ICRA)*. Saint Paul, MN, May 2012 DOI:10.1109/ICRA.2012.6225318   .
- [28] A. Censi, M. Håkansson, and R. M. Murray. “Fault detection and isolation from uninterpreted data in robotic sensorimotor cascades”. In: *Proceedings of the IEEE International Conference on Robotics and Automation (ICRA)*. **Best student paper finalist**. May 2012 DOI:10.1109/ICRA.2012.6225311   .
- [32] D. Scaramuzza, A. Censi, and K. Daniilidis. “Exploiting motion priors in visual odometry for vehicle-mounted cameras with non-holonomic constraints”. In: *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. San Francisco, CA, Sept. 2011 DOI:10.1109/IROS.2011.6095123 .
- [29] A. Censi and R. M. Murray. “Uncertain semantics, representation nuisances, and necessary invariance properties of bootstrapping agents”. In: *Joint IEEE International Conference on Development and Learning and Epigenetic Robotics*. Frankfurt, Germany, Aug. 2011 DOI:10.1109/DEVLRN.2011.6037313  .
- [30] A. Censi and R. M. Murray. “Bootstrapping sensorimotor cascades: a group-theoretic perspective”. In: *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. San Francisco, CA, Sept. 2011 DOI:10.1109/IROS.2011.6095151  .
- [31] A. Censi and R. M. Murray. “Bootstrapping bilinear models of robotic sensorimotor cascades”. In: *Proceedings of the IEEE International Conference on Robotics and Automation (ICRA)*. **Best conference paper finalist**. Shanghai, China, May 2011 DOI:10.1109/ICRA.2011.5979844   .
- [33] S. Han, A. Censi, A. D. Straw, and R. M. Murray. “A bio-plausible design for visual pose stabilization”. In: *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. Taipei, Taiwan, Oct. 2010, pp. 5679–5686 DOI:10.1109/IROS.2010.5652857  .
- [34] A. Censi, S. Han, S. B. Fuller, and R. M. Murray. “A bio-plausible design for visual attitude stabilization”. In: *Proceedings of the 48th IEEE Conference on Decision and Control*. Shanghai, China, Dec. 2009 DOI:10.1109/CDC.2009.5400408  .
- [35] A. Censi. “On the performance of Kalman filtering with intermittent observations: a geometric approach with fractals”. In: *Proceedings of the American Control Conference (ACC)*. St. Louis, Missouri, June 2009 DOI:10.1109/ACC.2009.5159869   .
- [36] A. Censi. “On achievable accuracy for pose tracking”. In: *Proceedings of the IEEE International Conference on Robotics and Automation (ICRA)*. Kobe, Japan, May 2009 DOI:10.1109/ROBOT.2009.5152236   .
- [37] S. Carpin and A. Censi. “An experimental assessment of the HSM3D algorithm for sparse and colored data”. In: *Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. St. Louis, MO, Oct. 2009, pp. 3595–3600 DOI:10.1109/IROS.2009.5354618.
- [38] A. Censi and S. Carpin. “HSM3D: Feature-Less Global 6DOF Scan-Matching in the Hough/Radon Domain”. In: *Proceedings of the IEEE International Conference on Robotics and Automation (ICRA)*. Kobe, Japan, May 2009 DOI:10.1109/ROBOT.2009.5152431   .
- [39] A. Censi and R. M. Murray. “Real-valued consensus over noisy quantized channels”. In: *Proceedings of the American Control Conference (ACC)*. St. Louis, Missouri, June 2009 DOI:10.1109/ACC.2009.5159872   .
- [40] D. Calisi, A. Censi, L. Iocchi, and D. Nardi. “OpenRDK: A Modular Framework for Robotic Software Development”. In: *Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. Nice, France, Sept. 2008 DOI:10.1109/IROS.2008.4651213   .
- [41] A. Censi, D. Calisi, A. D. Luca, and G. Oriolo. “A Bayesian framework for optimal motion planning with uncertainty”. In: *Proceedings of the IEEE International Conference on Robotics and Automation (ICRA)*. Pasadena, CA, May 2008 DOI:10.1109/ROBOT.2008.4543469   .
- [42] A. Censi. “An ICP variant using a point-to-line metric”. In: *Proceedings of the IEEE International Conference on Robotics and Automation (ICRA)*. Pasadena, CA, May 2008 DOI:10.1109/ROBOT.2008.4543181   .
- [43] A. Censi and G. D. Tipaldi. “Lazy Localization using the Frozen-Time Smoother”. In: *Proceedings of the IEEE International Conference on Robotics and Automation (ICRA)*. Pasadena, CA, May 2008 DOI:10.1109/ROBOT.2008.4543631  .
- [44] A. Censi, L. Marchionni, and G. Oriolo. “Simultaneous maximum-likelihood calibration of robot and sensor parameters”. In: *Proceedings of the IEEE International Conference on Robotics and Automation (ICRA)*. Pasadena, CA, May 2008 DOI:10.1109/ROBOT.2008.4543516   .
- [45] A. Censi. “An accurate closed-form estimate of ICP’s covariance”. In: *Proceedings of the IEEE International Conference on Robotics and Automation (ICRA)*. Rome, Italy, Apr. 2007, pp. 3167–3172 DOI:10.1109/ROBOT.2007.363961   .

- [46] A. Censi. "On achievable accuracy for range-finder localization". In: *Proceedings of the IEEE International Conference on Robotics and Automation (ICRA)*. Rome, Italy, Apr. 2007, pp. 4170–4175 DOI:10.1109/ROBOT.2007.364120   .
- [47] A. Censi. "Scan matching in a probabilistic framework". In: *Proceedings of the IEEE International Conference on Robotics and Automation (ICRA)*. Orlando, Florida, May 2006, pp. 2291–2296 DOI:10.1109/ROBOT.2006.1642044   .
- [48] A. Censi, L. Iocchi, and G. Grisetti. "Scan matching in the Hough domain". In: *Proceedings of the IEEE International Conference on Robotics and Automation (ICRA)*. Barcelona, Spain, 2005, pp. 2739–2744 DOI:10.1109/ROBOT.2005.1570528   .