

Nick Bottenus

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Education

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| Ph.D. | 2011–2017 | Duke University, Pratt School of Engineering
Department of Biomedical Engineering
Thesis: Ultrasound Beamforming Methods for Large Coherent Apertures
Advisor: Gregg Trahey |
| B.S.E | 2007–2011 | Duke University, Pratt School of Engineering
Department of Biomedical Engineering
Department of Electrical and Computer Engineering
<i>Summa Cum Laude</i> |

Research Experience

Assistant Professor 2020–Present

University of Colorado Boulder, Department of Mechanical Engineering, Boulder, CO

The Bottenus Lab is focused on developing system-level solutions to problems in diagnostic ultrasound imaging, using complementary transducer sampling, acoustic signal processing, and image interpretation methods to more robustly provide doctors with useful information across varied patient populations and applications.

Research Scientist 2017–2019

Duke University, Department of Biomedical Engineering, Durham, NC

Diagnostic ultrasound imaging research for improving image quality through advances in signal and array processing. Clinical translation and evaluation of beamforming methods.

Chief Science Officer 2018–2019

MicroElastic Ultrasound Systems, Durham, NC

Leading algorithm development and pre-clinical research for a new ultrasonic elasticity device. Participating in development and prototyping of the low-cost, portable device based on radiation force excitation.

Pre-doctoral Fellow 2011–2017

Duke University, Department of Biomedical Engineering, Durham, NC

Studied diagnostic ultrasound imaging. Developed and published research on synthetic aperture imaging, spatial coherence, displacement estimation, and image quality. Advised by Gregg Trahey.

Student Intern/Co-op

2013–2014

Siemens Healthcare, Mountain View, CA

Performed commercial ultrasound scanner image optimization and software development. Researched synthetic aperture and spatial coherence imaging methods.

Awards and Honors

2023	Boettcher Investigator
2020	IEEE UFFC Star Ambassador Lectureship Award
2017	Duke BME Award for Outstanding Doctoral Dissertation
2016	IEEE International Ultrasonics Symposium Student Travel Support
2015	SPIE Medical Imaging Robert F. Wagner Best Student Paper Award Finalist
2015	SPIE Medical Imaging Cum Laude Poster Award
2013	NSF Graduate Research Fellowship Program - Honorable Mention
2011–2014	Duke Medical Imaging Training Program Pre-doctoral Fellowship

Grant Activity

Active funding

Funding source: Boettcher Webb Waring Biomedical Research Award

Role: Principal Investigator

Project title: Binding kinetics of targeted microbubble agents

Funding period: June 2023 – May 2026

Description: We propose to study the complex binding behaviors of targeted microbubbles in vitro and in animal model using ultrafast and super-resolution imaging techniques. We seek to accelerate molecular imaging scans and improve their sensitivity by better understanding transient behaviors.

Funding source: Colorado Office of Economic Development & International Trade

Role: Principal Investigator

Project title: Decoding multipulse ultrasound imaging data (DO 2022-2448)

Funding period: May 2022 – April 2024

Description: We propose to apply delay-based array encoding to increase acquisition speed and signal quality in cardiac exams. These improvements will enable higher quality real-time sequences for difficult-to-image patients.

Funding source: NIH National Institute of Biomedical Imaging and Bioengineering

Role: Principal Investigator

Project title: Optically tracked freehand swept synthetic aperture ultrasound (R03-EB032090)

Funding period: August 2021-May 2024

Description: We propose to build an optically-tracked system to enable coherent combination of ultrasound data from multiple transducer positions, allowing a sonographer to extend the effective

aperture size and improve resolution beyond conventional limits for difficult-to-image patients.

Completed funding

Funding source: University of Colorado Boulder Engineering Excellence Fund

Role: Principal Investigator

Project title: Bringing Point of Care Ultrasound to the Classroom

Funding date: March 2023

Description: Integrate a point of care ultrasound device into hands-on ultrasound physics, device, and signal processing education. Funds matched from Undergraduate and Graduate Mechanical Engineering committees

Funding source: NIH National Institute of Biomedical Imaging and Bioengineering

Role: Principal Investigator (subaward) (PI: Trahey)

Project title: A Patient-Adaptive, High MI Abdominal Scanner (R01-EB026574)

Funding period: July 2021 – August 2022

Description: Develop accelerated voltage sweep sequence for adaptive imaging, analyze spatial and temporal coherence relationships, lead submission of a review on the use of spatial coherence in ultrasound imaging.

Funding source: Duke-Coulter Translational Partnership

Role: Research Scientist, 50% time (PI: Trahey)

Project title: Intrapulse Spatial Compounding

Funding period: Sep 2017 – Aug 2018

Description: Clinical translation of beamforming methods from sole-author paper, “Recovery of the complete data set from focused transmit beams”, for applications in cardiac imaging

Funding source: Duke-Coulter Translational Partnership, seed funding

Role: Research Scientist, 64.3% time (PI: Trahey)

Project title: Intrapulse Spatial Compounding

Funding period: Feb 2017 – Aug 2017

Description: Development of beamforming methods from sole-author paper, “Recovery of the complete data set from focused transmit beams”

Peer-Reviewed Journal Publications

Bold indicates PI role

Underline indicates supervised student is primary (first) author

J. Lee; R.R. Raj; C.P. Thome; N.B. Day; P. Martinez; N. Bottenus; A. Gupta; C.W. Shields. “Bubble-based microrobots with rapid circular motions for epithelial pinning and drug delivery”. *Small*. vol. 19, no. 32, p. 2300409. Aug 2023. <https://doi.org/10.1002/smll.202300409>

Bottenus, N; “Implementation of Constrained Swept Synthetic Aperture Using a Mechanical Fixture”. *Applied Sciences*. vol. 13, no. 8, 4797. Apr 2023. <https://doi.org/10.3390/app13084797>.

Zhang, B.; Bottenus, N.; Jin, F.; Nightingale, K.; “Quantifying the Impact of Imaging through Body Walls on Shear Wave Elasticity Measurements”. *Ultrasound in Medicine & Biology*. vol. 49, no. 3. pp. 734–749. Mar 2023. <https://doi.org/10.1016/j.ultrasmedbio.2022.10.005>

Bottenus, N.; Spainhour, J., Becker, S.; “Comparison of spatial encodings for ultrasound imaging”. *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*. vol. 70, no. 1, pp. 52–63. Jan 2023. <https://doi.org/10.1109/TUFFC.2022.3228218>

IEEE TUFFC Jan 2023 Cover article

Martinez, P.; Bottenus, N.; Borden, M.; “Cavitation Characterization of Size-Isolated Microbubbles in a Vessel Phantom using Focused Ultrasound”. *Pharmaceutics*. vol. 14, no. 9, 1925. Sep 2022. <https://doi.org/10.3390/pharmaceutics14091925>

Long, J.; Trahey, G.; **Bottenus, N.**; “Spatial coherence in medical ultrasound - a review”. *Ultrasound in Medicine & Biology*. vol. 48, no. 6, pp. 975–996. Apr 2022. <https://doi.org/10.1016/j.ultrasmedbio.2022.01.009>

Hyun, D.; Kim, G.; Bottenus, N.; Dahl, J.; “Ultrasound Lesion Detectability as a Distance Between Probability Measures”. *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*. vol. 69, no. 2, pp. 732–743. Feb 2022. <https://doi.org/10.1109/TUFFC.2021.3138058>

Inzunza-Ibarra, M.; Navarro-Becerra, J.A.; Narumanchi, V.; Bottenus, N.; Murray, T.; Borden, M.; “Enhanced visibility through microbubble-induced photoacoustic fluctuation imaging”. *JASA Express Letters*. vol. 2, no. 1. Jan 2022. <https://doi.org/10.1121/10.0009129>

JASA Express Letters Jan 2022 Cover article

Ahmed, R.; Bottenus, N.; Long, J.; Trahey, G.; “Reverberation Clutter Suppression Using 2D Spatial Coherence Analysis”. *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*. vol. 69, no.1, pp. 84–97. Jan 2022. <https://doi.org/10.1109/TUFFC.2021.3108059>

Offerdahl, K.; Huber, M.; Long, W.; Bottenus, N.; Nelson, R.; Trahey, G.; “Occult Regions of Suppressed Coherence in Liver B-Mode Images”. *Ultrasound in Medicine & Biology*. vol. 48, no. 1, pp. 47–58. Jan 2022. <https://doi.org/10.1016/j.ultrasmedbio.2021.09.007>

Flint, K.; Bottenus, N.; Bradway, D.; McNally, P.; Ellestad, S.; Trahey, G.; “An automated ALARA method for ultrasound: an obstetric feasibility study.” *Journal of Ultrasound in Medicine*. vol. 40, no. 9, pp. 1863–1877. Sep 2021. <https://doi.org/10.1002/jum.15570>

Long, J.; Bottenus, N.; Trahey, G.; “Frequency-dependent spatial coherence in conventional and chirp transmissions”. *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*. vol. 68, no. 5, pp. 1487–1495. May 2021. <https://doi.org/10.1109/TUFFC.2021.3050120>

Bottenus, N.; Byram, B.; Hyun, D.; “Histogram matching for visual assessment of ultrasound images”. *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*. vol. 68, no. 5, pp. 1487–1495. May 2021. <https://doi.org/10.1109/TUFFC.2020.3035965>

Bottenus, N.; LeFevre, M.; Cleve, J.; Crowley, A.L.; Trahey, G.; “Resolution and Speckle Reduction

in Cardiac Imaging.” *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*. vol. 68, no. 4, pp. 1131–1143. Apr 2021. <https://doi.org/10.1109/TUFFC.2020.3034518>

Farling, S.; Straube, T.; Vesel, T.; Bottenus, N.; Klitzman, B.; Cheifetz, I.; Deshusses, M.; “Development of a Novel Intravascular Oxygenator Catheter: Oxygen Mass Transfer Properties Across Non-Porous Hollow Fiber Membranes”. *Biotechnology and Bioengineering*. vol. 118, pp. 345–356. 2021. <https://doi.org/10.1002/bit.27574>

Long, J.; Long, W.; Bottenus, N.; Trahey, G.; “Coherence-Based Quantification of Acoustic Clutter Sources in Medical Ultrasound”. *Journal of the Acoustical Society of America*. vol. 148, pp.1051–1062. Aug 2020. <https://doi.org/10.1121/10.0001790>

Huang, O.; Long, W.; Bottenus, N.; Lerendegui, M.; Trahey, G.; Farsiu, S.; Palmeri, M.; “Mimick-Net, Matching Clinical Post-Processing Under Realistic Black-Box Constraints”. *IEEE Transactions on Medical Imaging*. vol. 39, no. 6, pp. 2277–2286. Jun 2020. <https://doi.org/10.1109/TMI.2020.2970867>

Long, W.; Bottenus, N.; Trahey, G.E; “Incoherent Clutter Suppression using Lag-One Coherence”. *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 67, no. 8, pp. 1544–1557. Aug. 2020. <https://doi.org/10.1109/TUFFC.2020.2977200>

Caenen, A.; Knight, A.; Rouze, N.; Bottenus, N.; Segers, P.; Nightingale, K.; “Analysis of multiple shear wave modes in a nonlinear soft solid: experiments and finite element simulations with a tilted acoustic radiation force.” *Journal of the Mechanical Behavior of Biomedical Materials*, vol. 107, Jul 2020. <https://doi.org/10.1016/j.jmbbm.2020.103754>

Abadi E.; Segars W.; Tsui B.; Kinahan P.; Bottenus, N.; Frangi A.; Maidment A.; Lo J.; Samei A.; “Virtual Clinical Trials in Medical Imaging”. *Journal of Medical Imaging*, vol. 7, no. 4, Jul/Aug 2020. <https://doi.org/10.1117/1.JMI.7.4.042805>

Morgan, M; Bottenus, N.; Trahey, G.; Walker, W. “Synthetic Aperture Focusing for Multi-covariate Imaging of Sub-resolution Targets”. *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 67, no. 6, pp. 1166–1177. Jun 2020. <https://doi.org/10.1109/TUFFC.2020.2966116>

Ali, R.; Herickhoff, C.D.; Hyun, D.; Dahl, J.J.; **Bottenus, N.** “Extending Retrospective Encoding for Robust Recovery of the Multistatic Dataset”. *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 67, no. 5, pp. 943–956. May 2020. <https://doi.org/10.1109/TUFFC.2019.2961875>

Bottenus, N.; Pinton, G.; Trahey, G; “The Impact of Acoustic Clutter on Large Array Abdominal Imaging.”. *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 67, no. 4, pp. 703–714. Apr 2020. <https://doi.org/10.1109/TUFFC.2019.2952797>

Long, W.; Bottenus, N.; Trahey, G.; “Lag-One Coherence as a Metric for Ultrasonic Image Quality”. *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 65, no. 10, pp. 1768–1780. Oct 2018. <https://doi.org/10.1109/TUFFC.2018.2855653>

Dec 2018, Dec 2019, Feb 2020 Editor’s Selection, Nov 2019 Highly Cited recognition

Bottenus, N. “Comparison of virtual source synthetic aperture beamforming with an element-based model”. *Journal of the Acoustical Society of America*, vol. 143, pp. 2801–2812. May 2018. <https://doi.org/10.1121/1.5036733>

Bottenus, N.; Long, W.; Morgan, M; Trahey, G.; “Evaluation of large aperture imaging through the ex vivo human abdominal wall”. *Ultrasound in Medicine and Biology*, vol. 44, no. 3, pp. 687–701. Mar 2018. <https://doi.org/10.1016/j.ultrasmedbio.2017.10.019>

Bottenus, N.; “Recovery of the complete data set from focused transmit beams” *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control*, vol. 65, no. 1, pp. 30–38. Jan 2018. <https://doi.org/10.1109/TUFFC.2017.2773495>

Jul 2018, Mar 2019 Highly Cited recognitions

Jakovljevic, M.; Bottenus, N.; Kuo, L.; Kumar, S.; Dahl, J.; Trahey, G. “Blocked Elements in 1-D and 2-D Arrays Part II: Compensation Methods as Applied to Large Coherent Apertures”. *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control*, vol. 64, no. 6, pp. 922–936, Jun 2017. <https://doi.org/10.1109/TUFFC.2017.2683562>

Heyde, B.; Bottenus, N.; D’hooge, J.; Trahey, G.; “Evaluation of the transverse oscillation technique for cardiac phased-array imaging: A theoretical study”. *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control*, vol. 64, no. 2, pp. 320–334, Feb 2017. <https://doi.org/10.1109/TUFFC.2016.2622818>

Oct 2017 Editor’s Selection recognition

Bottenus, N.; Long, W.; Zhang, H.K.; Jakovljevic, M.; Bradway, D.P.; Boctor, E.M.; Trahey, G.E.; “Feasibility of Swept Synthetic Aperture Imaging”. *IEEE Transactions on Medical Imaging* vol. 35, no. 7, Jul 2016. <https://doi.org/10.1109/TMI.2016.2524992>

Zhang, H.K.; Bottenus, N.; Cheng, A; Guo, X.; Trahey, G.E.; Boctor, E.M.; “Synthetic Tracked Aperture Ultrasound (STRATUS) Imaging: Design, Simulation, and Experimental Evaluation”. *Journal of Medical Imaging* vol. 3, no. 2, Apr 2016. <https://doi.org/10.1117/1.JMI.3.2.027001>

Bottenus, N.; Trahey, G.E.; “Evaluation of the transverse oscillation method using the Cramer-Rao Lower Bound”. *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control*, vol. 62, no. 11, pp. 2009–2017, Nov 2015. <https://doi.org/10.1109/TUFFC.2015.007135>

Hollender, P.; Bottenus, N.; Trahey, G.; “A multi-resolution approach to shear wave image reconstruction.” *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control*, vol. 62, no. 8, pp.1429–1439, Aug 2015. <https://doi.org/10.1109/TUFFC.2014.006400>

Bottenus, N.; Ustuner, K.F.; “Acoustic reciprocity of spatial coherence in ultrasound imaging”. *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control*, vol. 62, no. 5, pp.852–861, May 2015. <https://doi.org/10.1109/TUFFC.2014.006928>

Bottenus, N.; Trahey, G.E.; “Equivalence of time and aperture domain additive noise in ultrasound coherence”. *Journal of the Acoustical Society of America*, vol. 137, pp.132–138, Jan 2015. <https://doi.org/10.1121/1.4904530>

Bottenus, N.; Byram, B.C.; Dahl, J.J.; Trahey, G.E.; “Synthetic aperture focusing for short-lag spatial coherence imaging”. *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control*, vol. 60, no. 9, pp.1816–1826, Sep 2013. <https://doi.org/10.1109/TUFFC.2013.2768>

Book Chapters

Bottenus, N.; “Forming Large Effective Ultrasound Arrays Using The Swept Synthetic Aperture Technique.” In Rasooly, A.; Ossandon, M.R.; Baker, H.; (Eds.) *Biomedical Engineering Technologies: Volume 1*. Springer US, New York, NY. pp. 683–699. 2022. https://doi.org/10.1007/978-1-0716-1803-5_37

Patents

Patents granted

Hollender, P.; Bottenus, N.. “Methods, Systems and Computer Program Products for Multi-resolution Imaging and Analysis,” US patent No. 10,194,889

Ustuner, K.; Bottenus, N.; “Coherence Ultrasound Imaging with Broad Transmit Beams,” US patent No. 10,064,602.

Boctor, E.; Trahey, G.; Bottenus, N.; Zhang, H.; “Synthetic Aperture Ultrasound System,” US patent No. 10,349,917

Trahey, G.; Long, W.; Hollender, P.; Bradway, D.; Kakkad, V.; Bottenus, N.; “Methods, Systems, and Computer Program Products for Triggering Ultrasound Data Acquisition,” US patent No. 10,969,487

Patent applications

Bottenus, N.. “Decoding multipulse ultrasound data”. in review, Provision Patent Application 63/272,155.

Bottenus, N.; Trahey, G.. “Systems and Methods for Intra-Beam Compounding for Ultrasound Imaging,” in review, Application 16/621,785, PCT/US2018/040015.

Long, J.; Trahey, G.; Bottenus, N.; Long, W.; “Adaptive Ultrasound Frequency Selection.” in review, Application 17/080,467

Invited Talks

Invited conference presentations

Spainhour, J.; Becker, S.; Bottenus, N.; “The impact of loss function domain for optimizing ultrasound imaging”. *183rd Meeting of the Acoustical Society of America*. December 2022.

Bottenus, N.; “Field II Simulation for Fast, Flexible Insight into Ultrasound Design”, *2022 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2022.

Invited seminars

“Harnessing motion for high-resolution ultrasound imaging”. *Department of Imaging Physics, UT MD Anderson Cancer Center*, virtual, May 3, 2022

“Pushing ultrasound clearer, further, faster”. *Department of Biomedical Engineering, University of North Carolina Chapel Hill*, Chapel Hill, NC. April 5, 2022

“Pushing ultrasound clearer, further, faster”. *Department of Biomedical Engineering, Duke University*, Durham, NC. April 4, 2022

“REFoCUS: No-compromise focusing for the software beamforming age”. *Siemens Healthineers*, Mountain View, California. May 4, 2017

“REFoCUS: Ultrasound beamforming for the undecided and unknown”. *Stanford University*, Stanford, California. May 2, 2017

“Ultrasound beamforming methods for large coherent apertures”. *Vanderbilt University*, Nashville, Tennessee. April 28 2017.

“Applied synthetic aperture methods: summed receive signal coherence and swept synthetic aperture imaging”. *Technical University of Denmark*, Lyngby, Denmark. June 11 2015.

Internal seminars

“Ultrasound is on the move! High-resolution imaging through motion”. *BME Seminar Series, CU Boulder*, November 17, 2024.

Conference Presentations and Posters

Bold indicates PI role (senior/sole author)

Underline indicates supervised student is primary (first) author

Proceedings linked where available

Lee, J.; Raj, R.; Thome, C.; Day, N.; Martinez, P.; Bottenus, N.; Gupta, A.; Shields, C.W.; “Bubble-Based Microrobots for Epithelial Pinning and Sustained Drug Delivery”, *2023 AIChE Annual Meeting*. November 2023

Sanchez, A.; Javadi, N.; **Bottenus, N.**; “Feasibility of Optical Tracking for Swept Synthetic Aperture Imaging”. *2023 IEEE International Ultrasonics Symposium*. September 2023

Javadi, N.; **Bottenus, N.**; “Beamforming Approaches for Reconstruction of Overlapping Wavefields in Multi-Line Transmit Imaging”. *2023 IEEE International Ultrasonics Symposium*. September 2023

Lee, J.; Raj, R.; Thome, C.; Day, N.; Martinez, P.; Bottenus, N.; Gupta, A.; Shields, C.W.; “Bubble-based microrobots for epithelial pinning and drug delivery in the bladder”, Controlled Release Society 2023, July 2023.

Spainhour, J.; Becker, S.; **Bottenus, N.**; “A Strategy for Synthetic Aperture Sequence Design using Numerical Optimization”. *2022 IEEE International Ultrasonics Symposium*. October 2022. <https://doi.org/10.1109/IUS54386.2022.9958070>

Herrema, B.; **Bottenus, N.**; “Mixed Imaging Sequences for Improved Spatiotemporal Resolution in Cardiac Imaging”. *2022 IEEE International Ultrasonics Symposium*. October 2022. <https://doi.org/10.1109/IUS54386.2022.9957629>

Purh, T.; Chauhan, A.; McDonnell, P.; Jayaram, K.; Bottenus, N.; Mukherjee, D.; “Understanding Particle Transport In Human Vascular Network Using In Vitro Benchtop Flow Modeling.” 2022 APS Division of Fluid Dynamics Meeting. November 2022.

Purh, T.; Chauhan, A.; McDonnell, P.; Jayaram, K.; Bottenus, N.; Mukherjee, D.; “Designing a Benchtop Flow Loop for Investigating Particle Transport in Human Arterial Flows”. 2022 Rocky Mountain Fluid Mechanics Symposium. August 2022.

Bottenus, N.; “Encoded synthetic aperture imaging”. *Artimino 2022 Medical Ultrasound Technology meeting*, June 2022

Herrema, B.; **Bottenus, N.**; “Motion sensitivity of encoded ultrasound beamforming”. *Artimino 2022 Medical Ultrasound Technology meeting*, June 2022

Parham, M.; **Bottenus, N.**; “Optical tracking for swept synthetic aperture imaging”. *Artimino 2022 Medical Ultrasound Technology meeting*, June 2022

Huber, M.; Flint, K.; Bottenus, N.; Trahey, G.; “Estimation of Temporal Noise Using Spatial Coherence During Adaptive Acoustic Output Selection in Ultrasound Imaging.” *American Institute of Ultrasound in Medicine 2022 Meeting*. March 2022

Bottenus, N.; “Decoding multiline transmit ultrasound data for synthetic focusing.” *SPIE Medical Imaging 2022*, February 2022. <https://doi.org/10.1117/12.2610699>

Inzunza-Ibarra, M.; Narumanchi, V.; Navarro-Becerra, J.; Bottenus, N.; Murray, T.; Borden, M.; “Overcoming the Photoacoustic Limited-View Problem via Microbubble Induced Fluctuation Imaging”. *2021 UFFC Latin America Ultrasonics Symposium*. Oct 2021

Bottenus, N.; “Improving Signal-to-Noise Ratio Through Generalized Multi-Pulse Transmit Encoding.” *2021 IEEE International Ultrasonics Symposium*, September 2021. <https://doi.org/10.1109/IUS52206.2021.9593443>

Ahmed, R.; Bottenus, N.; Long, J.; Trahey, G.; “Detection And Suppression Of Partially Correlated Reverberation Clutter Using Matrix Arrays.” *2021 IEEE International Ultrasonics Symposium*, September 2021

Hyun, D.; Dahl, J.; **Bottenus, N.;** “Real-time universal synthetic transmit aperture beamforming with REFoCUS.” *2021 IEEE International Ultrasonics Symposium*, September 2021. <https://doi.org/10.1109/IUS52206.2021.9593648>

Hyun, D.; Kim, G.; Bottenus, N.; Dahl, J.; “Key considerations for using the generalized contrast-to-noise ratio.” *2021 IEEE International Ultrasonics Symposium*, September 2021

Brighton, I.; **Bottenus, N.;** “Acoustic signal injection for reverse engineering of signal formation.” *2021 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2021

Ahmed, R.; Bottenus, N.; Long, J.; Bradway, D.; Trahey, G.; “In vivo Lag-one Coherence Measurements Using Matrix Arrays.” *2021 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2021

Bottenus, N.; Straube, T.; Farling, S.; Vesel, T.; Klitzman, B.; Deshusses, M.; Cheifetz, I.; “Ultrasonic bubble detection and tracking using spatial coherence and motion modeling.” *Proc. SPIE 11602, Medical Imaging 2021: Ultrasonic Imaging and Tomography*, February 2021. <https://doi.org/10.1117/12.2580587>

Long, J.; Long, W.; Bottenus, N.; Trahey, G.; “Coherence-based quantification of acoustic clutter sources in medical ultrasound.”. *179th Meeting of the Acoustical Society of America*, Dec 2020

Offerdahl, K.; Huber, M.; Long, J.; Long, W.; Bottenus, N.; Trahey, G.; “Occult regions of suppressed coherence in ultrasonic liver images”. *179th Meeting of the Acoustical Society of America*, Dec 2020

Huber, M.; Flint, K.; Long, J.; Long, W.; Bottenus, N.; Trahey, G.; “Real-time, patient-adaptive ultrasonic intensity adjustment: Hepatic imaging observations.”. *179th Meeting of the Acoustical Society of America*, Dec 2020

Flint, K.; Bottenus, N.; Bradway, D.; McNally, P.; Ellestad, S.; Trahey, G.; “A feasibility study of automated ultrasound transmit power adjustment”. *RSNA 2020*, Dec 2020

Hyun, D.; Kim, G.; Bottenus, N.; Dahl, J.; “A measure-theoretic perspective of lesion detectability”. *2020 IEEE International Ultrasonics Symposium*, September 2020.

Long, J.; Bottenus, N.; Trahey, G.; “Congruence of frequency-dependent spatial coherence between linear frequency-modulated pulses and conventional pulses”. *2020 IEEE International Ultrasonics Symposium*, September 2020. <https://doi.org/10.1109/IUS46767.2020.9251466>

Huber, M.; Long, J.; Flint, K.; Long, W.; Bottenus, N.; Trahey, G.; “Implementation of adaptive transmit parameter adjustment in ultrasound imaging.” *2020 IEEE International Ultrasonics Symposium*, September 2020. <https://doi.org/10.1109/IUS46767.2020.9251354>

Caenen, A.; Knight, A.; Rouze, N.; Bottenus, N.; Segers, P.; Nightingale, K.; “Shear wave elastography : a non-invasive alternative for multi-axial mechanical testing? Proof of concept in a nonlinear tissue-mimicking phantom”. *SB3C 2020, Summer Biomechanics, Bioengineering, and Biotransport Conference*, June 2020. <http://hdl.handle.net/1854/LU-8666851>

Bottenus, N.; “Estimation of transducer translation using channel-domain correlation.” *2019 IEEE International Ultrasonics Symposium*, October 2019. <https://doi.org/10.1109/ULTSYM.2019.8925652>

Morgan, M.; Flint, K.; Long, W.; Bottenus, N.; McNally, P.; Ellestad, S.; Trahey, G.; Walker, W.; “Multi-Covariate Imaging of Sub-Resolution Targets: Clinical Feasibility Study”. *2019 IEEE International Ultrasonics Symposium*, October 2019

Ali, R.; Dahl, J.J; **Bottenus, N.**. “Iterative Retrospective Recovery of Full Synthetic Aperture Data from Focused Transmissions.” *2019 IEEE International Ultrasonics Symposium*, October 2019. <https://doi.org/10.1109/ULTSYM.2019.8925717>

Caenen, A.; Knight, A.E.; Rouze, N.C; Bottenus, N.; Segers, P.; Nightingale, K.R.; “Measuring elastic nonlinearity in a soft solid using a tilted acoustic radiation force for shear wave excitation.” *2019 IEEE International Ultrasonics Symposium*, October 2019. <https://doi.org/10.1109/ULTSYM.2019.8926155>

Huang, O.; Long, W.; Bottenus, N.; Trahey, G.E.; Farsiu, S.; Palmeri, M.L.; “MimickNet, Matching Clinical Post-Processing Under Realistic Black-Box Constraints”. *2019 IEEE International Ultrasonics Symposium*, October 2019. <https://doi.org/10.1109/ULTSYM.2019.8925597>

Bottenus, N., LeFevre, M.; Cleve, J.; Crowley, A.L.; Trahey, G.; “K-space Compounding for Improved Endocardial Border Detection.” *2019 IEEE International Ultrasonics Symposium*, October 2019. <https://doi.org/10.1109/ULTSYM.2019.8925620>

Bottenus, N.; “Constrained swept synthetic aperture imaging without external tracking.” *2019 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2019

Long, W.; Bottenus, N.; Trahey, G.; “Adaptive clutter subtraction in B-mode imaging using lag-one coherence (LOC).” *2019 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2019

Long, J.; Long, W.; Bottenus, N.; Trahey, G.; “Adaptive Frequency Selection Using Lag One Coherence”. *2019 AIUM Convention*. April 2019.

Flint, K.; Bottenus, N.; Long, W.; Bradway, D.; McNally, P.; Ellestad, S.; Trahey, G. “Preliminary Clinical Evaluation of an Automated Fetal ALARA System”. *2019 AIUM Convention*. April 2019.

Bottenus, N.; “REFoCUS: Ultrasound focusing for the software beamforming age.” *2018 IEEE International Ultrasonics Symposium*, October 2018. <https://doi.org/10.1109/ULTSYM.2018.8580195>

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Ali, R.; Dahl, J.; Bottenus, N.; “Regularized inversion method for frequency-domain recovery of the full synthetic aperture dataset from focused transmissions.” *2018 IEEE International Ultrasonics Symposium*, October 2018. <https://doi.org/10.1109/ULTSYM.2018.8580213>

Long, J.; Long, W.; Bottenus, N.; Pinton, G.; Trahey, G.; “Implications of lag-one coherence on real-time adaptive frequency selection.” *2018 IEEE International Ultrasonics Symposium*, October 2018. <https://doi.org/10.1109/ULTSYM.2018.8580063>

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Caenen, A.; Hollender, P.; Bottenus, N.; Segers, P.; Trahey, G.; Palmeri, M.; “Investigating the degree of shear wave speed anisotropy as a function of studied ventricular zone.” *2018 IEEE International Ultrasonics Symposium*, October 2018. <https://doi.org/10.1109/ULTSYM.2018.8580228>

Long, W.; Bottenus, N.; Nelson, R.; Trahey, G.; “Characterization of B-mode image quality using lag-one coherence (LOC)”. *2018 IEEE International Ultrasonics Symposium*, October 2018.

Bottenus, N.; Kakkad, V.; Long, W.; Flint, K.; Bradway, D.; Lefevre, M.; Trahey, G.; “Cardiac image quality reflected by spatial and temporal coherence.” *2018 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2018

Bottenus, N.; “Synthetic recovery of the complete harmonic data set”. *SPIE Medical Imaging 2018: Ultrasonic Imaging and Tomography*, February 2018. <https://doi.org/10.1117/12.2293760>

Bottenus, N.; “Recovery of the complete data set from ultrasound sequences with arbitrary transmit delays”. *174th Meeting of the Acoustical Society of America*, December 2017. <https://doi.org/10.1121/2.0000662>

Bottenus, N.; Long, W.; Morgan, M.; Trahey, G.; “Swept synthetic aperture study of large aperture imaging through ex vivo human abdominal wall”. *2017 IEEE International Ultrasonics Symposium*, September 2017

Dahl, J.; Hyun, D.; Li, Y.; Jakovljevic, M.; Bell, M.; Long, W.; Bottenus, N.; Kakkad, V.; Trahey, G.; “Coherence Beamforming and Its Applications to the Difficult-To-Image Patient”. *2017 IEEE International Ultrasonics Symposium*, September 2017. <https://doi.org/10.1109/ULTSYM.2017.>

Hollender, P; Bottenus, N.; Bradway, D.; Trahey, G.; “Single Track Location Comb-Push Ultrasound Shear Elastography (STL-CUSE)”. *2017 IEEE International Ultrasonics Symposium*, September 2017. <https://doi.org/10.1109/ULTSYM.2017.8091901>

Trahey, G.; Bottenus, N.; Pinton, G.; “Beamforming methods for large aperture imaging”. *172nd Meeting of the Acoustical Society of America*, June 2017

Morgan, M.; Bottenus, N.; Trahey, G.; “Beamforming challenges in swept synthetic aperture imaging”. *2017 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2017

Bottenus, N.; Long, W.; Morgan, M.; Pinton, G.; Trahey, G.; “Simulated and ex vivo large aperture imaging through human abdomen”. *2017 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2017

Heyde, B.; Bottenus, N.; Trahey, G.; D’hooge, J.; “Impact of Beamforming Strategies and Regularisation on Ultrasound Displacement Estimation Using RF-Based Image Registration”. *2017 IEEE International Symposium on Biomedical Imaging*, April 2017. <https://doi.org/10.1109/ISBI.2017.7950664>

Bottenus, N.; “A method for intrapulse spatial compounding”. *2016 IEEE International Ultrasonics Symposium*, September 2016. <https://doi.org/10.1109/ULTSYM.2016.7728504>

Bottenus, N.; Pinton, G.; Trahey, G.; “Large coherent apertures: improvements in deep abdominal imaging and fundamental limits imposed by clutter”. *2016 IEEE International Ultrasonics Symposium*, September 2016. <https://doi.org/10.1109/ULTSYM.2016.7728849>

Heyde, B.; Bottenus, N.; D’hooge, J.; Trahey, G.; “Impact of beamforming on deformation imaging with phased arrays: a comparison of transverse oscillations and traditional focused beamforming”. *2016 IEEE International Ultrasonics Symposium*, September 2016

Ramirez Jr., J; Bottenus, N.; Trahey, G; Krolik, J.L; “Synthetic Aperture Imaging with Thinned Linear Sensor Arrays for Medical Ultrasound”. *IEEE Sensor Array and Multichannel Signal Processing Workshop*, July 2016. <https://doi.org/10.1109/SAM.2016.7569640>

Bottenus, N.; Long, W; Trahey, G.; “Transmit beamforming strategies for Swept Synthetic Aperture imaging”. *2016 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2016

Heyde, B.; Bottenus, N.; D’hooge, J; Trahey, G.; “Benefits and limitations of the transverse oscillation technique for phased-array imaging”. *2016 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2016

Jakovljevic, M.; Bottenus, N.; Kuo, L; Kumar, S; Dahl, J; Trahey, G; “Detection of and Compensation for Blocked Elements using Large Coherent Apertures: Ex Vivo Studies”. *2016 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2016

Jakovljevic, M.; Bottenus, N.; Kuo, L; Kumar, S; Dahl, J; Trahey, G; “Detection of and Compensation for Blocked Elements using Large Coherent Apertures: Ex Vivo Studies”. *Proc. SPIE 9790, Medical Imaging 2016: Ultrasonic Imaging and Tomography*, April 2016. <https://doi.org/10.1117/12.2217385>

Bottenus, N.; Long, W; Bradway, D; Trahey, G.E.; “Phantom and in vivo demonstration of swept synthetic aperture imaging”. *2015 IEEE International Ultrasonics Symposium*, 21-25 October 2015. <https://doi.org/10.1109/ULTSYM.2015.0075>

Bottenus, N., Trahey, G.; “Large swept synthetic aperture imaging”. *Artimino Conference on Medical Ultrasound 2015*, June 2015

Zhang, H.K.; Bottenus, N.; Cheng, A.; Trahey, G.E.; Boctor, E.M.; “Synthetic-tracked aperture ultrasound imaging using robotic guidance”. *2015 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2015

Jakovljevic, M.; Bottenus, N.; Trahey, G.E.; “Ex-vivo measurements of ultrasonic wavefront distortion using large synthetic apertures across ribs and abdomen”. *2015 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2015

Bottenus, N.; Trahey, G.E.; Ustuner, K.F.; “Ultrasound coherence imaging using hardware receive beamforming and broad transmit beams”. *Proc. SPIE 9419, Medical Imaging 2015: Ultrasonic Imaging and Tomography*, February 23, 2015. <https://doi.org/10.1117/12.2081433>

Cum Laude Poster Award

Bottenus, N.; Jakovljevic, M.; Boctor, E.M.; Trahey, G.E.; “Implementation of swept synthetic aperture imaging”. *Proc. SPIE 9419, Medical Imaging 2015: Ultrasonic Imaging and Tomography*, February 22, 2015. <https://doi.org/10.1117/12.2081434>

Robert F. Wagner Best Student Paper Award Finalist

Bottenus, N.; Trahey, G.E.; “Time and aperture domain noise equivalence in coherence imaging”. *2014 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2014

Li, Y.L.; Cook, M.; Bottenus, N.; Dahl, J.J.; “Coherent flow imaging: detecting slow flow signal with backscatter spatial coherence”. *2014 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2014

Trahey, G.E.; Jakovljevic, M; Bottenus, N.; Boctor, E. “Swept Array Synthetic Aperture Imaging (SASAI)”. *2014 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2014

Hollender, P.J; Bottenus, N; Trahey, G.E.; “Robust Shear Wave Velocity Reconstruction From Multi-Resolution Time-of-Flight Estimates”. *Twelfth International Tissue Elasticity Conference*, October 2013

Bottenus, N.; Dahl, J.J.; Trahey, G.; “Apodization schemes for short-lag spatial coherence imaging.”. *2013 IEEE International Ultrasonics Symposium*, pp.1276-1279, 21-25 July 2013 <https://doi.org/10.1109/ULTSYM.2013.0326>

Dahl, J.J.; Bottenus, N.; Lediju Bell, M.A.; Cook, M.J.; “Coherent flow imaging: A power Doppler imaging technique based on backscatter spatial coherence,”. *2013 IEEE International Ultrasonics Symposium*, pp.639-642, 21-25 July 2013. <https://doi.org/10.1109/ULTSYM.2013.0165>

Bottenus, N.; Byram, B.C.; Dahl, J.J; Trahey, G.E.; “Synthetic-aperture image quality study of short-lag spatial-coherence imaging”. *2013 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2013

Bottenus, N.; Byram, B.C.; Trahey, G.E.; “A synthetic aperture study of aperture size in the presence of noise and in vivo clutter”. *Proc. SPIE 8675, Medical Imaging 2013: Ultrasonic Imaging, Tomography, and Therapy*, 86750S, March 29, 2013. <https://doi.org/10.1117/12.2006981>

Bottenus, N.; Hyun, D.; Dahl, J.; Trahey, G.; Byram, B.; “Application of synthetic aperture focusing to short-lag spatial coherence”. *2012 IEEE International Ultrasonics Symposium*, pp.2262-2265, 7-10 Oct. 2012. <https://doi.org/10.1109/ULTSYM.2012.0565>

Internal Presentations

“Ultrasound is on the move! High-resolution imaging through motion”. *Biomedical Engineering Graduate Seminar Series, University of Colorado Boulder*, Boulder, CO. November 17, 2023

“Harnessing motion for high-resolution ultrasound imaging”. *Biomedical Engineering Graduate Seminar Series, University of Colorado Boulder*, Boulder, CO. October 20, 2022

Bottenus, N.; “A practical overview of REFoCUS beamforming”. ULTRASONC 2019

Bottenus, N.; Long, W.; Bradway, D.; Trahey, G.E.; “Phantom and in vivo demonstration of swept synthetic aperture imaging”. *Duke Imaging Technology Fair 2015*, October 2015
“Most exciting new imaging technology” poster award

Bottenus, N.; Trahey, G.E.; Ustuner, K.F.; “Ultrasound coherence imaging using hardware receive beamforming and broad transmit beams”, *DCI Radiation Oncology & Imaging Program Annual Retreat 2015*, March 16, 2015

Bottenus, N.; Jakovljevic, M; Kuo, L.; Kumar, S; Boctor, E.M; Trahey, G.E.; “Swept Synthetic Aperture Ultrasound Imaging”. *Duke Imaging Technology Fair 2014*, October 2014
“Most exciting new image processing technology” poster award

Bottenus, N.; Hyun, D.; Dahl, J.; Trahey, G.; Byram, B.; “Application of synthetic aperture focusing to short-lag spatial coherence”. *2012 NIBIB Training Grantees Meeting*, June 2012

Teaching Experience

Instructor

University of Colorado Boulder

Semester	Number	Level	Title
2023 Fall	MCEN 4127/5127	Graduate	Biomedical Ultrasound
2023 Spring	ECEN 3301	Undergraduate	Biomedical Signals and Systems
2022 Spring	MCEN 2023	Undergraduate	Statics and Structures
2021 Fall	MCEN 4127/5127	Graduate	Biomedical Ultrasound
2021 Spring	MCEN 2023	Undergraduate	Statics and Structures
2020 Fall	MCEN 4127/5127	Graduate	Biomedical Ultrasound

Duke University

Semester	Number	Level	Title
2018 Fall	MP 734	Graduate	Non-ionizing Medical Imaging (co-instructor)
2017 Fall	MP 734	Graduate	Non-ionizing Medical Imaging (co-instructor)

Guest Lectures

Semester	Number	Lecture Title
2023 Spring	BMEN 1000	Seeing finer, further, faster
2022 Spring	Duke BME 844	Synthetic Aperture Ultrasound Imaging
2021 Spring	MCEN 3030	Signal Processing
2021 Spring	BMEN 1000	Seeing finer, further, faster
2021 Spring	MCEN 4228/5228	Mechanics of Ultrasound
2020 Spring	MCEN 4228/5228	Mechanics of Ultrasound
2018 Spring	BME 844	Synthetic Aperture Ultrasound Imaging
2017 Fall	BME 354	Introduction to Microcontrollers

Class projects

Semester	Number	Description
2020 Fall	Duke EGR101L	Bio-optical sensor enhancements to marine animal tags

Other

2020–2021 Assisting in development of BME 3030: Bioinstrumentation

Professional Service

Conference organizing co-chair:

2022–2024 SPIE Medical Imaging (Ultrasonic Imaging and Tomography)
2022 Artimino Medical Ultrasound Technology meeting

Conference session chair:

2022 Artimino Medical Ultrasound Technology meeting
2021–present SPIE Medical Imaging (Ultrasonic Imaging and Tomography)
2019–present IEEE International Ultrasonics Symposium
2017–present Ultrasonic Imaging and Tissue Characterization Symposium, Session chair

Professional committees

2024	Technical Program Committee – IEEE Latin America Ultrasonics Symposium
2022–present	Member of AAPM Task Group 387: Consensus Recommendations on reliable development and use of Virtual Imaging Trials

Grant reviewer for:

- NIH ITD (early career reviewer)
- CU Boulder RIO Seed Grant
- Inserm (Plan Cancer)

Journal reviewer for:

- Acta Biomaterialia
- IEEE Open Journal on Ultrasonics, Ferroelectrics and Frequency Control
- IEEE Robotics and Automation Letters
- IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control
- IEEE Transactions on Medical Imaging
- IEEE Transactions on Biomedical Imaging
- Journal of the Acoustical Society of America
- Journal of Medical Imaging
- Nature Communications
- Science Advances
- Ultrasonic Imaging
- Ultrasonics
- Ultrasound in Medicine & Biology

Outreach

2023	Conducted hands-on ultrasound workshops for on-campus middle- and high-school STEM summer camp (approx. 100 students) led by Stephen Becker
2018	Duke TIP Scholar Weekend teaching assistant - Biomedical Engineering
2016	Jordan High School Science Fair judge

Professional Memberships

2014 – Present	IEEE (Ultrasonics, Ferroelectrics and Frequency Control)
2021 – Present	SPIE
2017 – 2018	ASA

