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David S. Hayden

Research Vision and Interests

My research enables scientists to collect, analyze and react to observations at scale. By working towards automated interventions, the tools I build aim to make new experimental designs possible from what once were observational studies. Broadly, my research interests are in interpretable machine learning and computer vision, with special focus on Bayesian nonparametrics applied to time-series, distributions on manifolds and using uncertainty to guide decision making, analysis and experimental design.

Education

Spring 2021 **Ph.D. Computer Science**, *Massachusetts Institute of Technology*.
Thesis: Bayesian Nonparametric Tooling for Scalable Science
Adviser: John W. Fisher III

Spring 2014 **M.S. Computer Science**, *Massachusetts Institute of Technology*.
Thesis: Wearable-Assisted Social Interaction as Assistive Technology for the Blind
Adviser: Seth Teller (deceased)

Spring 2011 **B.S. Computer Science, B.S. Mathematics**, *Arizona State University*.
Thesis: Note-Taker: Enabling the Legally Blind to Take Notes in Class
Adviser: Sethuraman Panchanathan

Research Activity

2018 - Present **Social Interaction Analysis in Primates** (MIT, Research Assistant)
Long-term video and depth tracking (100s of hours) of genetically-modified primates resulting in the first evidence for primate animal models in autism research. Enabled by observing statistical differences in behavior between pairs of primates with/without the SHANK-3 gene. Published in Nature, 2019 [4].

2016 - Present **Bayesian Nonparametric Parts Modeling and the Joint Posterior Tracker** (MIT, Research Assistant)
Unsupervised learning of an articulated parts model by observing short video, depth, point cloud or mesh sequences of an object in motion and assuming that body and part dynamics are described by distributions on the Lie group of rigid-body transformations [3]. Multi-object tracking with explicit representation of uncertainty and exact posterior sampling. Automatic identification of ambiguous outcomes enables sparse, costly algorithmic or human-in-the-loop corrections [2] for rapid improvement of track quality.

2012 - 2014 **Wearable Social Interaction Assistance** (MIT, Research Assistant)
Jacket with discreet cameras recognizes proximate acquaintances, enabling social interaction analysis as well as serendipitous social interactions for the blind. Information is conveyed to the user through private, Morse-coded vibrations that don't disrupt interactions [11, 12].

2008 - 2011 **The Note-Taker** (ASU, Project Lead, Research Assistant)
Custom pan/tilt/zoom camera with visual servoing and image enhancement, enabling the legally blind to observe distant content and take notes with reduced board-note-board delay that causes them to fall behind. Synchronized video and handwritten notes enables efficient review [6, 8, 9, 10, 14].

Awards

Contributed to or directly earned over $1.2 million in grants, prizes and awards.

2019 McGovern Institute Neurotechnology (MINT) Grant* ($50k)
2018 NIH Grant 1R01MH111916-01A1* ($500k)
2018 McGovern Institute Neurotechnology (MINT) Grant* ($50k)
2016 NSF Graduate Research Fellowship ($141k)
2014 Google Glass Accessibility Award ($20k)
2011 IDSA Design Award (Silver)
2011 Microsoft Imagine Cup Software Design, 2nd Place Worldwide ($8k)
2011 Microsoft Imagine Cup Software Design, 1st Place Nationally
2010 Microsoft Imagine Cup Accessibility, 1st Place Worldwide ($8k)
2009 NSF Grant 0931278 (2009 - 2013)** ($500k)
2009 Additional (Google Lime, NASA MUST) ($15k)

*: Emerged as part of a collaboration between Rogier Landman and I.

**: Emerged from a project I started in Sethuraman Panchanathan's lab.

Publications

Published 15 papers: 9 conference/journal papers, 5 short/workshop papers, and 1 book chapter. Venues include Nature, Neurips, CVPR, ASSETS and CHI.

Conference and Journal Publications

1. Sue Zheng, David S. Hayden, Jason Pacheco, John W. Fisher III. Sequential Bayesian Experimental Design with Variable Cost Structure. *Neurips*, 2020.

2. David S. Hayden, Sue Zheng, John W. Fisher III. Efficient Data Association and Uncertainty Quantification for Multi-Object Tracking. *Arxiv*, 2020.

3. David S. Hayden, Jason Pacheco, John W. Fisher III. Nonparametric Object and Parts Modeling with Lie Group Dynamics . *CVPR*, 2020.

4. Yang Zhou, Jitendra Sharma, Qiong Ke, Rogier Landman, Jingli Yuan, Hong Chen, David S. Hayden et al.. Atypical Behaviour and Connectivity in SHANK3-Mutant Macaques. *Nature*, June, 2019.

5. David S. Hayden, Steve Chien, David R. Thompson, Rebecca Castaño. Using Clustering and Metric Learning to Improve Science Return of Remote Sensed Imagery. *ACM Transactions on Intelligent Systems and Technology*, 2012.

6. David S. Hayden, Michael Astrauskas, Qian Yan, Liqing Zhou, John A. Black Jr.. Note-Taker 3.0: an Assistive Technology Enabling Students who are Legally Blind to Take Notes in Class. *ACM ASSETS*, 2011.

7. David S. Hayden, Steve Chien, David R. Thompson, Rebecca Castaño. Using Onboard Clustering to Summarize Remotely Sensed Imagery. *IEEE Intelligent Systems*, 2012.

8. David S. Hayden, Liqing Zhou, Michael Astrauskas, John A. Black Jr.. Note-Taker 2.0: the Next Step Toward Enabling Students who are Legally Blind to Take Notes in Class . *ACM ASSETS*, 2010.

9. David S. Hayden, Dirk Colbry, John A. Black Jr., Sethuraman Panchanathan. Note-Taker: Enabling Students who are Legally Blind to Take Notes in Class . *ACM ASSETS*, 2008.

Book Chapters

10. David S. Hayden, Liqing Zhou, John A. Black Jr.. The Note-Taker: a Tablet PC Based Device that Helps Students Take and Review Classroom Notes. *The Impact of Tablet PCs and Pen-based Technology on Education, ISBN: 1557535744*, 2010.

Peer-Reviewed Short and Workshop Publications

11. David S. Hayden, Robert C. Miller, Seth Teller. Unobtrusive, Wearable Social Interaction Detection and Assistance. *CHI Workshop on Assistive Augmentation*, 2014.

12. David S. Hayden, Carl Vondrick, Stella Jia, Yafim Landa, Robert C. Miller, Antonio Torralba, Seth Teller. The Accuracy-Obtrusiveness Tradeoff for Wearable Vision Platforms. *CVPR Workshop on Egocentric Vision*, 2012.

13. David S. Hayden, Steve Chien, David R. Thompson, Rebecca Castano. Onboard clustering of aerial data for selective data return. *10th International Symposium on Artificial Intelligence, Robotics, and Automation in Space*, 2010.

14. John A. Black Jr., David S. Hayden. The Note-Taker: An assistive technology that allows students who are legally blind to take notes in the classroom. *CVPR Workshop: Computer Vision Applications for the Visual Impaired*, 2010.

15. David S. Hayden, Steve Chien, David R. Thompson, Rebecca Castano. Onboard clustering of aerial data for improved science return. *IJCAI Workshop on AI in Space*, 2009.

Teaching and Mentorship

2009–present **Student Mentor.** Advised/led multiple masters (7) and undergraduate (6) students at MIT and ASU across three projects. Cathy Wu is now an MIT professor.

1. Terryn D. Brunelle, *Object Detection for a Robotic Science Laboratory (2020)*
2. Fernando Herrera, *Vision-Driven Interventions in a Robotic Science Laboratory (2020)*
3. Yafim Landa, *Low-Latency Wearable Systems Integration (2013)*
4. Cathy Wu, *User Interaction with a Wearable Vision Assistant (2013)*
5. Sophie L. Diehl, *Sewing Patterns for a Wearable Vision Assistant (2013)*
6. Mike Rush, *Hardware Design of a Custom Pan/Tilt/Zoom Vision Assistance Camera (2011)*
7. Michael Fruchtman, *Aligning Video with Pen Strokes (2011)*
8. Qian Yan, *3D-Printed Design for a Fourth-Generation Note-Taker (2011)*
9. Michael Astrauskas, *Visual Servoing in a Vision Assistance Camera (2009 - 2011)*
10. Liqing Zhou, *3D-Printed Design for a Third-Generation Note-Taker (2010)*
11. Parth Pandya, *Notes Archiving for the Note-Taker (2010)*
12. Andrew Kelley, *Software Design for Aligned Video and Pen Notes (2009)*
13. Shashank Srinivas, *Image Enhancement for the Note-Taker (2009)*

2020 **Invited Lecture** *Harvard, Artificial Intelligence and Music*
Invited lecture on generative models for music generation. Created a lab where students created custom LSTM-based music learned from classical pieces of their choosing.

2013 **Teaching Assistant, Principles and Practices of Assistive Technology,** *MIT*
Created new lecture and lab on assistive technology for the blind. Gave a class lecture and ran multiple lab sessions. Facilitated student/client interactions.

Service

2020 **Assistive Technology (ATHack) Hackathon Co-Organizer**

2013 **Andrea Bocelli Foundation Workshop Organizer**

2013 **MIT Diversity Summit Panelist**

2012 **White House Science Fair with President Obama (Presenter)**

Research Talks

Given 20 academic talks at conferences, competitions and universities.

Tracking, Parts Modeling and Primate Behavior Analysis

Oct, 2020 Harvard
Oct, 2020 Broad Institute
Sept, 2020 Massachusetts Institute of Technology
Sept, 2020 Georgia Tech
Sept, 2020 Max Plank Institute for Intelligent Systems
Aug, 2020 Johns Hopkins University
Aug, 2020 National University of Singapore
July, 2020 Stanford University
June, 2020 Computer Vision and Pattern Recognition (CVPR) Oral

Wearable Social Interaction Assistance and Analysis

April, 2014 Conference of Human-Computer Interaction (CHI) Workshop
April, 2013 Andrea Bocelli Foundation Workshop
July, 2012 Andrea Bocelli Foundation Workshop

Note-Taker

July, 2011 Microsoft Imagine Cup World Finals, 2nd Place, Software Design
April, 2011 Microsoft Imagine Cup National Finals, 1st Place, Software Design
Oct, 2011 ACM SIGACCESS Conference on Computers and Accessibility (ASSETS) Oral
July, 2010 Microsoft Imagine Cup World Finals, 1st Place, Accessibility
Oct, 2010 ACM SIGACCESS Conference on Computers and Accessibility (ASSETS) Oral
Oct, 2008 ACM SIGACCESS Conference on Computers and Accessibility (ASSETS) Oral

Artificial Intelligence for Improved Science Return in Space

2010 i-SAIRAS
2009 IJCAI Workshop

Selected Press (with links)

2015 Slate
2012 Blind Ambition (Documentary)
2011 Boston Magazine
2011 NPR Science Friday
2011 Wired
2011 GeekWire
2011 Independent

Entrepreneurship and Industry Activity

Entrepreneurship

2012 - 2015 **Essistive Technologies** (Founder)
Startup in which the Note-Taker project was commercialized, bringing it to 100s of individuals with limited vision. Technology was licensed to Perkins Products as the ZoomCapture.

Industry

2015 **Novel View Synthesis for Stereo Panoramas** (Google, Intern)
Deep learning for synthesis of novel images trained from a 16-camera stereo rig. Demonstrated improved performance on images with difficult textures and out-of-sample views.

2011 **Coupling Visual Search and Language Models for Image Retrieval** (Google, Intern)
Integrated ad-based language models with visual search for improved image similarity metrics.

2008 - 2010 **Metric Learning for Improved Science Return** (NASA Jet Propulsion Lab, Intern)
Learned distance metric from multiple aerial image clusterings performed by scientists on the ground that could then be uploaded to spacecraft for automatic selection of data that better aligns with current mission objectives [5, 7, 15, 13].

References

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