DANIEL HAEHN
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haehn@seas.harvard.edu
https://danielhaehn.com

I am a biomedical imaging and visualization researcher who investigates how the study of brain connectivity and machine perception can help advance the understanding of biologically inspired artificial intelligence.

Education

2013–present **PhD Candidate in Computer Science, Harvard University** Cambridge, MA
Analyzing Brain Connectivity and Computing Machine Perception, expected graduation May 2019
Advisor: Hanspeter Pfister
Committee: Steven Gortler, Finale Doshi-Velez, Scott Kuindersma, Jeff W. Lichtman

2010 **Diplom (MSc) in Medical Computer Science, University of Heidelberg** Germany
Signal- and Image Processing
Thesis: Coronary Artery Centerline Extraction
Advisors: Hartmut Dickhaus, Ron Kikinis

2007 **Vordiplom (BSc) in Medical Computer Science, University of Heidelberg** Germany
with Honors, rank #1 of class, all study fees waived

Experience

Summer 2017 **Apple, Inc.** Cupertino, CA
Research Intern in Data Science

Summer 2014 **Mental Canvas** New York City, NY
Research Intern in Computer Graphics

2011–2013 **Boston Children's Hospital** Boston, MA
Research Software Developer III, Fetal Neonatal Neuroimaging and Developmental Science Center
Advisors: Rudolph Pienaar, P. Ellen Grant

2010–2011 **University of Pennsylvania** Philadelphia, PA
Research Scholar, Section for Biomedical Image Analysis
Advisor: Kilian Pohl

2009 **German Cancer Research Center (DKFZ) and BioQuant Center** Heidelberg, Germany
Research Assistant, Biomedical Computer Vision and Experimental Radiology Research Groups
Advisors: Stefan Wörz, Hendrik von Tengg-Kobligk

2008–2009 **Brigham and Women's Hospital** Boston, MA
Fellow, Department of Radiology and the Surgical Planning Laboratory
Advisors: Ron Kikinis, Steve Pieper, Luca Antiga

Publications

2018 Daniel Haehn, James Tompkin, and Hanspeter Pfister. **Evaluating 'Graphical Perception' with CNNs**. *IEEE Transactions on Visualization and Computer Graphics (IEEE VIS)*.

2018 Daniel Haehn, Verena Kaynig, James Tompkin, Jeff W. Lichtman, and Hanspeter Pfister. **Guided Proofreading of Automatic Segmentations for Connectomics**. *IEEE Computer Vision and Pattern Recognition (CVPR)*.

2017 Daniel Haehn, John Hoffer, Brian Matejek, Adi Suissa-Peleg, Ali K. Al-Awami, Lee Kamentsky, Felix Gonda, Eagon Meng, William Zhang, Richard Schalek, Alyssa Wilson, Toufiq Parag, Johanna Beyer, Verena Kaynig, Thouis R. Jones, James Tompkin, Markus Hadwiger, Jeff W. Lichtman, and Hanspeter Pfister. **Scalable Interactive Visualization for Connectomics**. *MDPI Informatics*.

2017 Brian Matejek, Daniel Haehn, Fritz Lekschas, Michael Mitzenmacher, and Hanspeter Pfister. **Compresso: Efficient Compression of Segmentation Data For Connectomics**. *Medical Image Computing and Computer-Assisted Intervention (MICCAI)*.

2017 Felix Gonda, Verena Kaynig, Thouis R. Jones, Daniel Haehn, Jeff W. Lichtman, Toufiq Parag, and Hanspeter Pfister. **ICON: An Interactive Approach to train Deep Neural Networks for Segmentation of Neuronal Structures**. *IEEE International Symposium on Biomedical Imaging (ISBI)*.

2017 Rudolph Pienaar, Ata Turk, Jorge Bernal-Rusiel, Nicolas Rannou, Daniel Haehn, P. Ellen Grant, and Orran Krieger. **CHIPS--A Service for Collecting, Organizing, Processing, and Sharing Medical Image Data in the Cloud**. *VLDB Workshop on Data Management and Analytics for Medicine and Healthcare*.

2016 Adi Suissa-Peleg, Daniel Haehn, Seymour Knowles-Barley, Verena Kaynig, Thouis R. Jones, Alyssa Wilson, Richard Schalek, Jeff W. Lichtman, and Hanspeter Pfister. **Automatic Neural Reconstruction from Petavoxel of Electron Microscopy Data**. *Microscopy and Microanalysis*.

2016 Ali K. Al-Awami, Johanna Beyer, Daniel Haehn, Narayanan Kasthuri, Jeff W. Lichtman, Hanspeter Pfister, and Markus Hadwiger. **NeuroBlocks--Visual Tracking of Segmentation and Proofreading for Large Connectomics Projects**. *IEEE Transactions on Visualization and Computer Graphics (IEEE VIS)*.

2016 Richard Schalek, Dong Lee, Narayanan Kasthuri, Adi Peleg, Thouis R. Jones, Verena Kaynig, Daniel Haehn, Hanspeter Pfister, David Cox, and Jeff W. Lichtman. **Imaging a 1 mm^3 Volume of Rat Cortex using a MultiBeam SEM**. *Microscopy and Microanalysis*.

2015 Kiho Im, Banu Ahtam, Daniel Haehn, Jurriaan M. Peters, Simon K. Warfield, Mustafa Sahin, and P. Ellen Grant. **Altered Structural Brain Networks in Tuberous Sclerosis Complex**. *Cerebral Cortex*.

2015 Rudolph Pienaar, Nicolas Rannou, Jorge Bernal, Daniel Haehn, and P. Ellen Grant. **ChRIS--A web-based Neuroimaging and Informatics System for Collecting, Organizing, Processing, Visualizing and Sharing of Medical Data**. *IEEE Engineering in Medicine and Biology Society (EMBC)*.

2014 Daniel Haehn, Seymour Knowles-Barley, Mike Roberts, Johanna Beyer, Narayanan Kasthuri, Jeff W. Lichtman, and Hanspeter Pfister. **Design and Evaluation of Interactive Proofreading Tools for Connectomics**. *IEEE Transactions on Visualization and Computer Graphics (IEEE VIS)*.

Publications (continued)

2013	Daniel Haehn, Nicolas Rannou, P. Ellen Grant, and Rudolph Pienaar. **Slice:Drop -- Collaborative Medical Imaging in the Browser**. *ACM SIGGRAPH Computer Animation Festival*.
2012	Daniel Haehn, Nicolas Rannou, Banu Ahtam, P. Ellen Grant, and Rudolph Pienaar. **Neuroimaging in the Browser using the X Toolkit.** *Frontiers in Neuroinformatics*.
2012	Myong-sun Choe, Silvia Ortiz-Mantilla, Nikos Makris, Matt Gregas, Janine Bacic, Daniel Haehn, David Kennedy, Rudolph Pienaar, Verne S. Caviness Jr, April A. Benasich, and P. Ellen Grant. **Regional Infant Brain Development: an MRI-based Morphometric Analysis in 3 to 13 month olds.** *Cerebral Cortex*.
2012	Arno Klein, Forrest S. Bao, Yrjö Häme, Eliezer Stavsky, Joachim Giard, Daniel Haehn, Nolan Nichols, and Satrajit S. Ghosh. **Mindboggle: Automated Human Brain MRI Feature Extraction, Labeling, Morphometry, and Online Visualization.** *Frontiers in Neuroinformatics*.
2012	Arno Klein, Nolan Nichols, and Daniel Haehn. **Mindboggle 2 interface: Online Visualization of Extracted Brain Features with XTK.** *Frontiers in Neuroinformatics*.

Mentoring

2018–present	Vincent Casser, Graduate student (MSc) at Harvard University
2018–present	Ian Svetkey, Pre-College student at Harvard University
2016	Eagon Meng, Undergraduate student at Harvard University
2015–2017	John Hoffer, Undergraduate student at Harvard University
2016	Omar Shaikh, Intern at Harvard University
2015	William Zhang, Intern at Harvard University
2013	Jay Andrew Robinson, Intern at Boston Children's Hospital (co-mentored)
2013	Emily Seibring, Intern at Boston Children's Hospital (co-mentored)
2010-2011	Suares Tamekue, Intern at Brigham and Women's Hospital (co-mentored)

Teaching

2018–present	TEALS Volunteer for AP Computer Science at Cambridge Rindge and Latin School
2016	Technical Assistant for the Deep Learning mini-course at the Harvard IACS Compute Fest
2015	Teaching Fellow for the Harvard CS171 Visualization course
2008	Workshop for Advanced Microcontroller Programming, University of Bratislava, Slovakia
2008	Workshop for Microcontroller Programming at the University of Tbilisi, Georgia (Europe)
2004–2008	Teaching Assistant for the Microcontrollers in EXperiment and LEarning (MEXLE) educational platform, Heilbronn University, Germany

Awards

2015–2019	Winkler Scholarship
2013–2019	Harvard University Fellowship
2013	Real-Time Live! presentation of Slice:Drop at SIGGRAPH
2012	INCF Neuroinformatics Spotlight Award for XTK
2012	Mozilla Hacks WebGL Dev Derby Runner-up for Slice:Drop
2012	Visualizing.org VisWeek Challenge Winner with Slice:Drop
2010	1st Prize for End User Tutorial at the National Alliance of Medical Image Computing (NA-MIC)
2008–2009	Karl Steinbuch Foundation Scholarship
2007–2009	Thomas Gessmann Foundation Scholarship

Presentations

2018	Paper presentation at **IEEE Visualization**: *Evaluating 'Graphical Perception' with CNNs*
2018	**Harvard Visual Computing Group** meeting presentation: *The 7 Levels of Open Science*
2018	Invited speaker at **Brown CS**: *Analyzing Brain Connectivity and Computing Machine Perception*
2018	Invited speaker at **IBM Research** (AI Systems Day): *Evaluating 'Graphical Perception' with CNNs*
2017	**Harvard Visual Computing Group** meeting presentation: *Guided Proofreading of Automatic Segmentations for Connectomics*
2016	Invited speaker at the **IEEE Visualization Doctoral Colloquium**: *Proofreading for Connectomics*
2015	**Harvard Lichtman Lab** meeting presentation: *Interactive Proofreading Tools for Connectomics*
2014	Paper presentation at **IEEE Visualization**: *Design and Evaluation of Interactive Proofreading Tools for Connectomics*
2014	**Harvard Visual Computing Group** meeting presentation: *Proofreading Tools for Connectomics*
2014	Invited speaker at the **MIT Computer Graphics Group**: *Web-based Visualization of Scientific Data*
2014	**Harvard Visual Computing Group** meeting presentation: *Interactive Proofreading with Dojo*
2014	**Harvard Lichtman Lab** meeting presentation: *Web-based Visualization and Proofreading for Connectomics*
2013	**Harvard Visual Computing Group** meeting presentation: *Web-based Scientific Visualization*
2013	Invited speaker at **Visualizing Biological Data (VIZBI)**: *Physiology & Function*
2012	Spotlight presentation at **INCF Neuroinfomatics**: *Neuroimaging in the Browser using the X Toolkit*
2012	Invited speaker at **WebGL Camp Orlando**: *WebGL for Baby Brains*

Service and Outreach

2019–present	Voluntary Advisor for the AP Data Science Curriculum in Cambridge Public Schools
2018–present	Head Coach for Cambridge Youth Soccer
2018	Volunteer+Presentation Facilitator at the Cambridge 8th Grade Science & Engineering Showcase
2013–present	Social Media Coordinator at the Harvard Visual Computing Group

Service and Outreach (continued)

2018–present	Reviewer for *Manning Publications*
2016–present	Reviewer for *Frontiers in Neuroinformatics*, *ISMRM*, *Neuroinformatics*, *Frontiers in Neural Circuits*, *ACM SIGCHI*, *IEEE CVPR*
2013	Technical Reviewer for *Matsuda and Lea: WebGL Programming Guide, Addison-Wesley*
2014–present	Principal Investigator for multiple IRB approved research studies by the Harvard Human Research Protection Program
2007–2010	President of the Student Computer Club at Heilbronn University, StuWoNet e.V.
2007–2009	Voluntary Project Lead of RANDI2, a randomization software for clinical trials at the German Cancer Research Center (DKFZ), coordinating 15+ developers
1997–1999	Vice-President of The German Computer Freaks, a National Cyber Security Club

My Erdős Number is 3.

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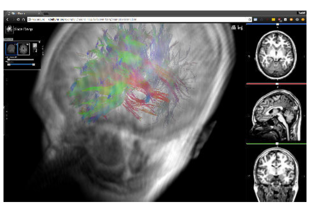
Video summary of my research: https://danielhaehn.com/research/

Research Statement

Artificial intelligence is loosely inspired by neuroscientific discoveries. However, existing methods are fragile and do not generalize well. In contrast, the brain allows humans to reliably recognize, extrapolate, and classify enormous amounts of stimuli–seemingly without effort. This difference in performance is likely the result of limited architectural correspondences between neurobiology and machine learning. With advances in computer science, my goal is *to reduce the gap between natural and artificial intelligence*: First, with bottom-up investigations for how visual computing methods can aid brain connectivity analysis, and in turn, how neurobiological insights can improve machine intelligence. Second, exploring top-down how perceptual studies can increase the comprehension of machine learning models, along with how explanatory analysis can lead to better applications of these algorithms.

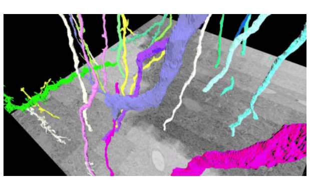
Analyzing Brain Connectivity

Connectivity analysis at different scales aims to demystify how the brain works. Macro-scale investigations focus on connections at the brain area level while micro-scale studies analyze neuronal connectivity at the synapse level. For both scales, I create visual computing methods to accelerate neuroscience research.



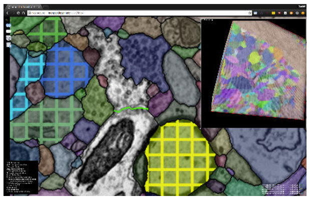
Slice:Drop visualizes MRI data in the web browser using volume rendering.

Macro-scale. Structural and functional magnetic resonance imaging paired with diffusion tensor imaging allows for connectivity analysis at (sub-)millimeter resolution. A variety of data formats, different radiological conventions, and the need for rapid analysis and diagnostics require visualization and processing methods that are fast, reliable, and collaborative. I designed XTK, the first neuroimaging framework for visualizing, interacting, and processing medical imaging data in the web browser. Building off this platform, my front-end application Slice:Drop provides a web-based graphical experience in 2D/3D comparable to traditional radiology workstations. My application enables real-time rendering and the sharing of standard medical data formats across multiple devices. This work has won several awards and contributed to medical advancement in brain development research. [Front. in Neuroinformatics 2012; SIGGRAPH Real-time Live! 2013; Cerebral Cortex 2012, 2015]



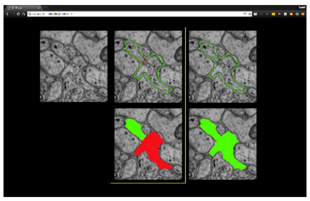
The twenty largest neurons in a 100μm cube of rat cortex processed with BUTTERFLY.

Micro-scale. In connectomics, modern electron microscopes produce petabyte volumes of brain images at nanometer resolution. The typical processing pipeline includes image acquisition, 3D volume registration, membrane segmentation of neurons, proofreading of labeling errors, and network graph analysis. Each step of this workflow requires automatic computing methods to handle vast amounts of data. Additionally, each step requires specialized visualization techniques to allow human verification. I created BUTTERFLY, a scalable platform for interactive web-based visualization and processing for every step of the connectomics pipeline. This platform



Web-based Dojo allows interactive proofreading of automatic neuron segmentations by multiple users in parallel.

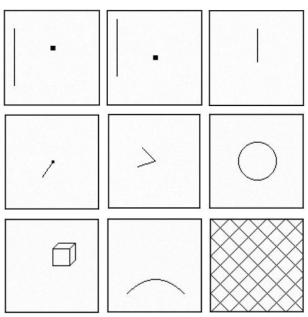
interfaces with Dojo, my web-based visual proofreading software, which allows novice users to interactively find and correct errors in automatic neuron segmentations. Further research then identified the visual search for these errors as the bottleneck for interactive corrections. Thus, I developed the Guided Proofreading system: a machine learning algorithm that automatically finds and recommends potential segmentation errors to the user. Corrections can then be performed with yes/no decisions which make it easier for both novices and experts to proofread successfully. This reduces search and error correction times and allows faster generation of ground truth label data. [IEEE Vis 2014, 2016; Microscopy and Microanalysis 2016; MDPI Informatics 2017; CVPR 2018]



The Guided Proofreading system reduces error correction of segmentations to yes/no decisions by leveraging machine learning.

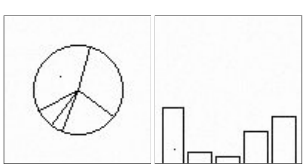
Future work. Neurobiological datasets will further increase in size, demanding improved automatic processing methods. However, such methods require large amounts of training data generated through expensive manual labeling. I aim to reduce this cost with active learning and semi-supervised methods. Yet, even with less manual labor, significant computational challenges remain, leaving the need for novel computer vision, visualization, and interaction methods to better understand neural connectivity and pathologies. Advancements here will allow us to better reverse-engineer neural circuits, yielding new artificial intelligence that, in turn, can improve the automatic processing of biological data.

Computing Machine Perception



Convolutional neural networks are able to estimate elementary visual encodings but fail when slight variations are introduced.

Artificial neural networks have been successfully applied to a wide range of visual tasks but struggle to generalize when slight variations are introduced. For instance, I observed that convolutional neural networks (CNNs) are able to predict the length of an ordinary line with great precision but struggle if the width of the line is slightly varied across testing stimuli. This experiment is part of a series of questions I explore with modern neural networks by replicating Cleveland and McGill's seminal 1984 studies of human perception. In this work, I train neural networks to estimate elementary perceptual encodings including angles, curvature, volumes, and textures. I also compare machines against humans when measuring perceptual capabilities of more complex visualizations such as pie charts, bar charts, and point clouds. While under limited circumstances CNNs are able to meet or outperform human task performance, I have found that modern architectures do not match human graphical perception capabilities. [IEEE Vis 2018]



Human perceptual capabilities favor bar charts over pie charts, which is also true for current artificial neural networks.

Future work. Systems for machine perception eventually need to be capable of abstraction and reasoning rather than applying memorization and interpolation. Promising approaches are capsule networks that include compartments for learning different visual attributes and the recent CORnet framework that replicates the ventral visual pathway. I aim to continue the systematic evaluation of existing and future neural network architectures to model human graphical perception. This requires artificial intelligence that is designed closer to its natural counterpart. Progress in neurobiology, hand in hand with machine perception research, is necessary to reach this goal.

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Teaching Statement

I love the energy of academic institutions: Discussing ideas with my peers, collaborating on new research efforts, and then riding the wave of excitement after project kick-off for as long as possible. For me as a scholar, there is nothing more valuable than the buzzing creative minds in this world coming together at a university, and I now want to be part of this community as a professor.

My goal is to equip the next generation of computer scientists with practical skills, preparing them to solve real world problems using computational methods. To this end, I have shared my knowledge and experience with high school students, undergraduate and graduate students, as well as large online communities. I am convinced that effective learning is active, not passive. Therefore, my teaching style follows a *learning-by-doing* philosophy and supports theoretical foundations with a multitude of examples and applications.

Lectures and Workshops

In my classroom, high school students use red cups to request assistance, and white cups to offer help to their peers. This allows me to quickly scan the room and it reduces the students' feeling of being put on the spot. (Concept by Doug McGlathery)

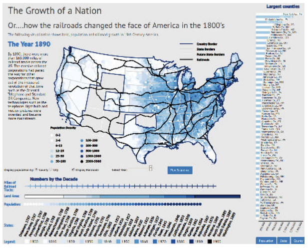
High School. I am a volunteer for the Technology Education and Literacy in Schools (TEALS) program supporting the Advanced Placement Computer Science course at the Cambridge Rindge and Latin School. This course aims to create a solid foundation of coding skills for motivated high school students. In this setting, I can see the immediate impact of my teaching: During assignments, students use colored cups to signal whether they are making progress, request my help, or are able to offer assistance to their fellow classmates. There is great reward in watching students pass on skills, that I had just imparted to them, to their peers with excitement.

College. The Microcontrollers in EXperiment and LEarning (MEXLE) initiative at Heilbronn University provides a hands-on learning experience of computer science with low-cost microcontrollers and circuit boards. As a teaching assistant for this platform I designed and taught programming tutorials used by 300+ undergraduate students in the engineering department and at international workshops. With access to extensive documentation and resources, students enjoyed combining software and hardware and delivered impressive final projects.

Students program the MEXLE circuit board to dynamically control a magnet to hover a soccer ball on a goal line. (Rudolf Kern)

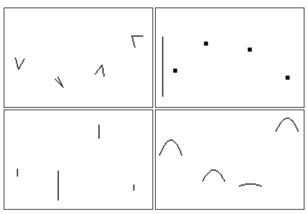
At Harvard, I helped teach Visualization to 200+ college students. As a teaching fellow, I headed sections for over twenty students, taught tutorials and coding sessions for individuals as well as smaller groups, and offered regular office hours. Some students were experienced coders, while others had minimal working knowledge. With humor and the ability to relate to individual skill levels, my goal was to build confidence in the students and to keep them motivated. When grading, I thought it was just as important to explain students' mistakes in detail as it was to praise good work. I followed the same approach when mentoring five final projects–of which one was selected as the runner-up of the course.

1-on-1 Mentoring



Interactive visualization of how railroads changed North America, a runner-up awarded student project for the Visualization course at Harvard. (Lauren Wood)

Pre-College Students. I mentored four high school students during individual research projects at Boston Children's Hospital and at Harvard. These young researchers were very motivated but easily overwhelmed due to little prior practical experience. I assessed each students' skill level and then proposed carefully tailored micro-tasks to keep them motivated while gradually directing them towards a final delivery. This approach worked well and the students succeeded to achieve their individual project goals. I am especially proud of two students who added significant research contributions as co-authors of publications and I was delighted when they later decided to concentrate in computer science as undergraduates at Columbia University and the University of Washington.

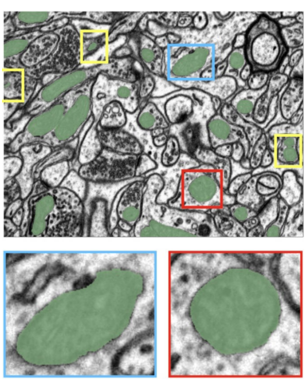


Pre-college research evaluating the 'graphical perception' of artificial neural networks on multi-stimuli data. (Ian Svetkey)

Undergraduate and Graduate Students. At Harvard, I was fortunate to supervise two undergraduates and one graduate student (MSc). Each individual required a custom mentoring approach, however, I always let the student drive and I emphasized creative freedom while regularly touching base. All three students became co-authors of my research papers.

Online Communities

I am an avid supporter of open science and open source software. One of my projects, XTK, the first web-based neuroimaging framework, reached 500+ stars and 180+ forks on Github. For developers, I created contribution guidelines, and for users, detailed tutorials. I also answered 70+ Stack Overflow questions for XTK, helping more than 28,000 people. As a member of the National Alliance for Medical Image Computing, I won the first prize for my 3D Slicer tutorial demonstrating how to segment and visualize coronary arteries using only software and data that was freely available.



My graduate student developed efficient segmentation methods for mitochondria in microscopy images. (Vincent Casser)

Future

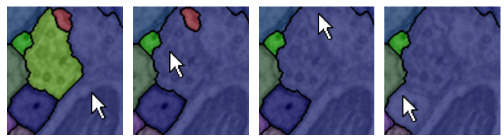
I want to establish professor-student relationships that break away from traditional hierarchies, emphasizing guidance and a supportive environment. As a teacher, I want to continue to be approachable for my students through regular meetings that are more often brainstorming sessions rather than progress reports. I want to motivate young minds and instill a level of confidence and critical thinking that allows them to leave the beaten path behind, abandon rigid research directions, and to think out-of-the-box. I envision a fluid learning environment with a soft boundary between teacher and student, where everybody involved is continuously growing. I also want to prioritize interdisciplinary research collaborations because working together is the key to solving real world problems efficiently. Ultimately, my motivation to becoming a professor is anchored in my core belief that knowledge has to be shared and I am ready to teach courses in scientific visualization, biomedical image processing, and web-based computer graphics.

Neuron Segmentation Proofreading with Dojo

Split Segments

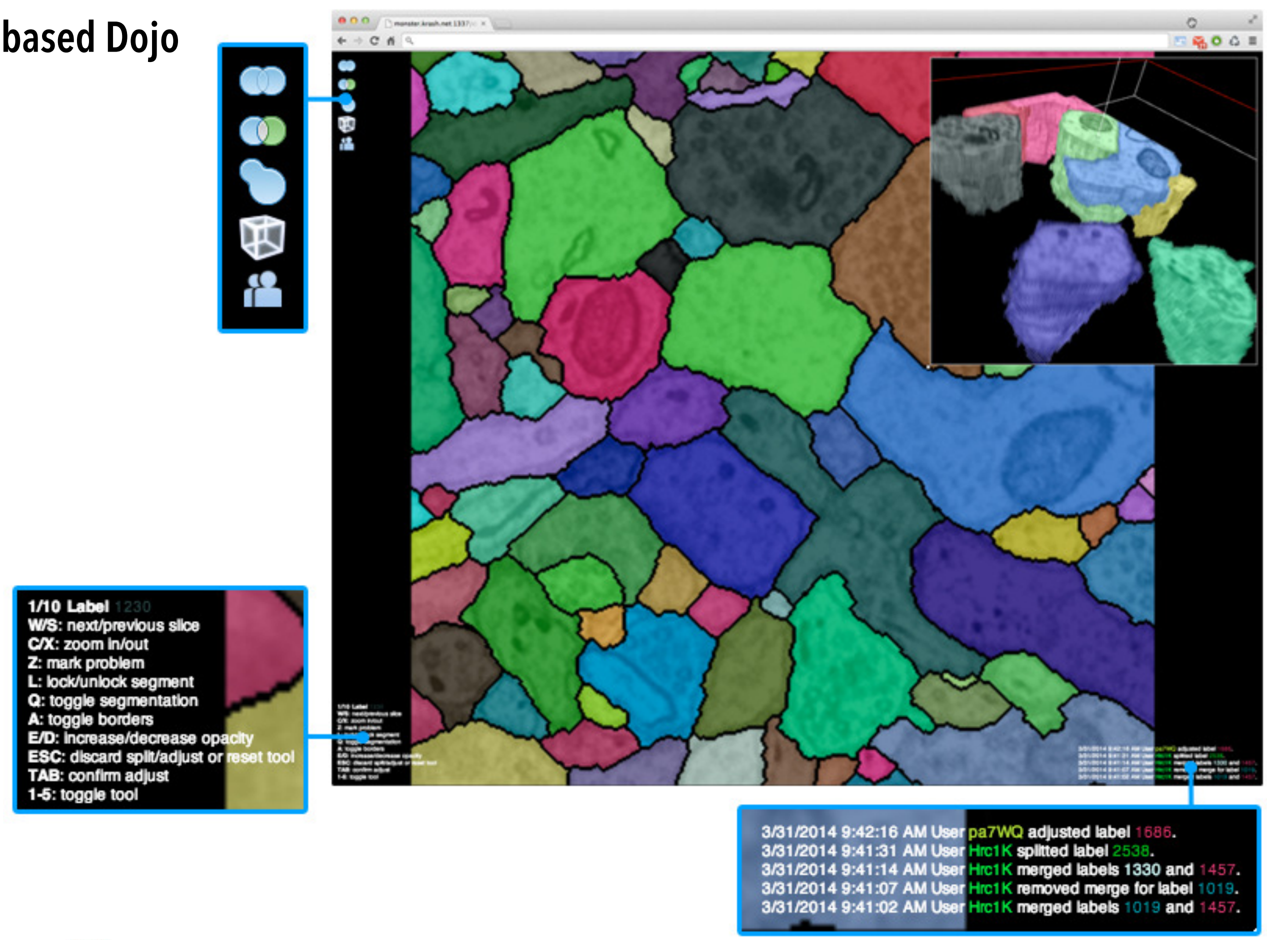
Before After

Merge Segments



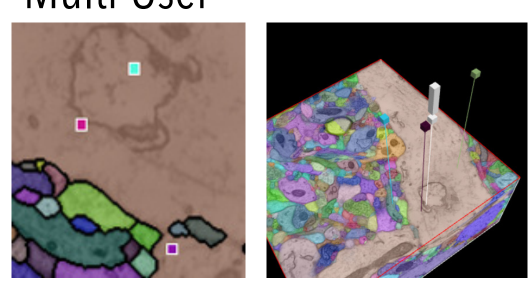
Before After

Web-based Dojo



Python / Javascript / WebGL

Multi-User



D. Haehn, S. Knowles-Barley, M. Roberts, J. Beyer, N. Kasthuri, J. W. Lichtman, and H. Pfister
Design and Evaluation of Interactive Proofreading Tools for Connectomics
IEEE Transactions on Visualization and Computer Graphics (IEEE VIS), 2014

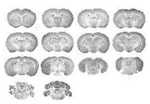
Guided Proofreading of Automatic Segmentations for Connectomics

Daniel Haehn, Verena Kaynig, James Tompkin, Jeff W. Lichtman, Hanspeter Pfister

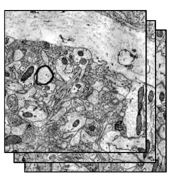
Connectome = neuron wiring

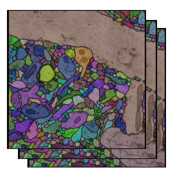

We take mice.


Extract brain.


Slice it thinly.

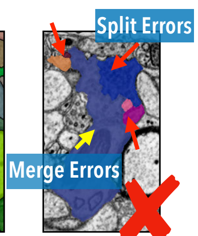

Scan with Electron Microscopy.


Acquire large, high-resolution image volumes.

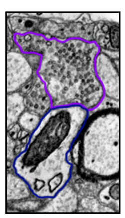

Perform automatic segmentations.

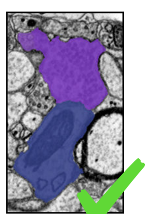
Automatic segmentations are not perfect and need human proofreading!


False labeling.

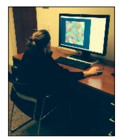


Errors.


Cell boundaries.


Correct labeling.

Interactive Proofreading

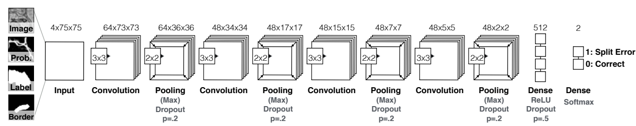


Visual search for errors and interactive corrections are **extremely time-consuming**!


Correcting Split Errors.

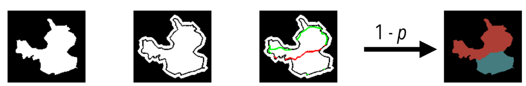

Correcting Merge Errors.

Guided Proofreading of Segmentations



We train a 4-layer multi-input CNN to find **split errors** with probability *p*.

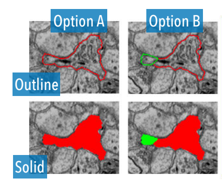
Training Data: 2k x 2k x 300 vx, 3 x 3 x 30 nm/vx, 112k correct and 112k error patches (75 x 75 px).



Merge Error. Dilated. Watershed Borders. Correction.

And re-use the same CNN for **merge errors**.

Our system suggests errors and reduces corrections to **yes/no decisions** with a **single-click user interface.**



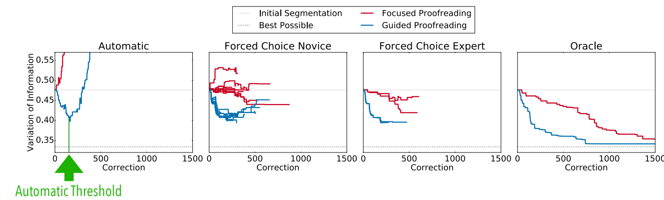
Experiments

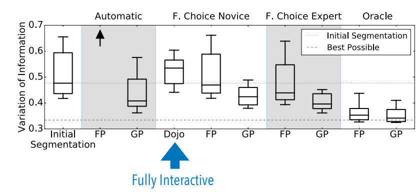
User study on the **Proofreading Benchmark** (400 x 400 x 40 vx)

Comparison with state-of-the-art **Focused Proofreading** (FP) [Plaza 2016]

2 x 10 Novices, 2 x 2 Experts, 30 minute time limit

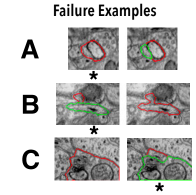
Measure Variation of Information (the lower, the better)





Our approach (GP) reduces manual labor for both novices as well as experts and is **7.5x** faster than interactive proofreading and FP.

Failure Examples



All participants correctly chose A, but had problems with B and C.

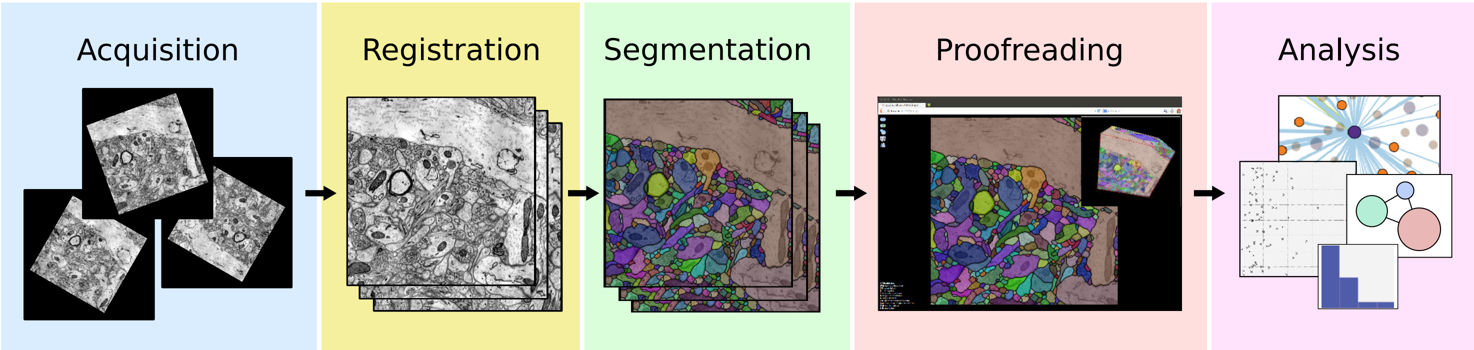
Conclusions

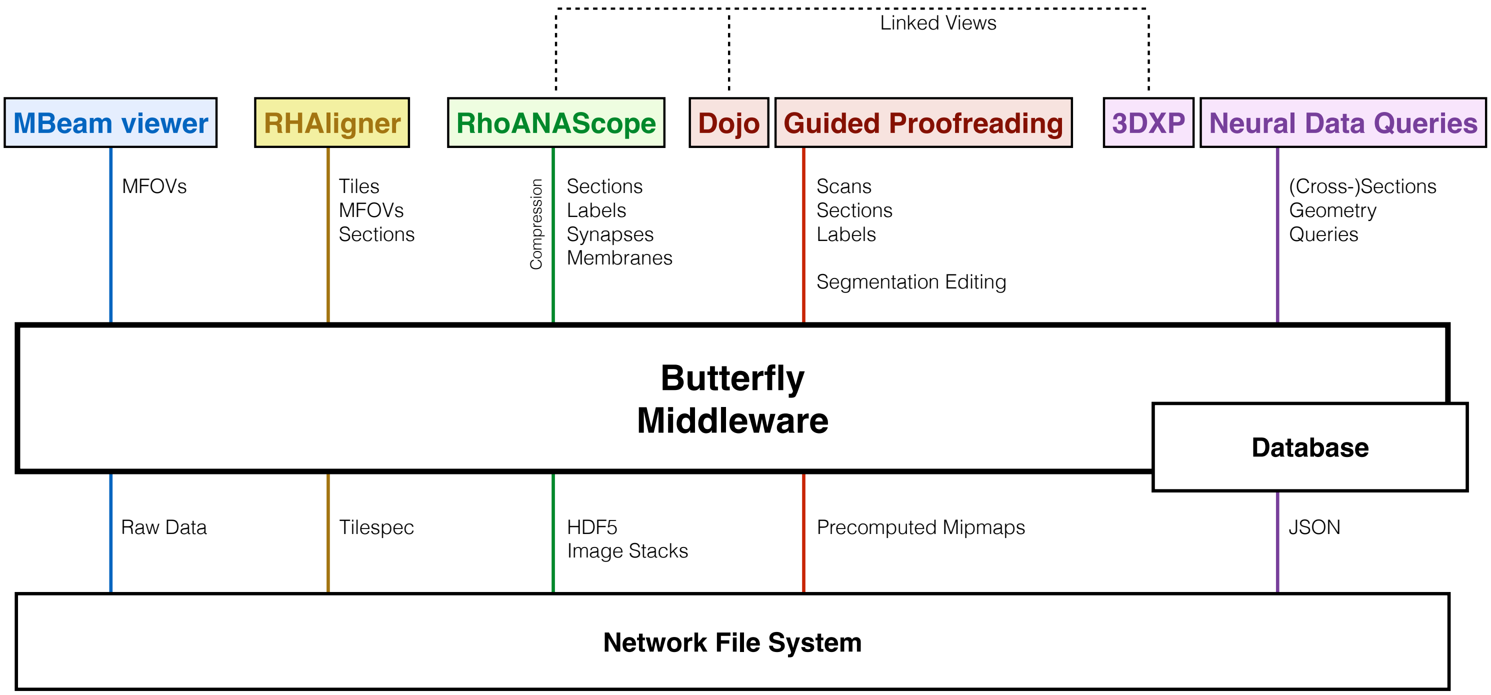
Guided Proofreading removes bottlenecks for humans in the error correction process and reduces the task to *only* the critical decision.

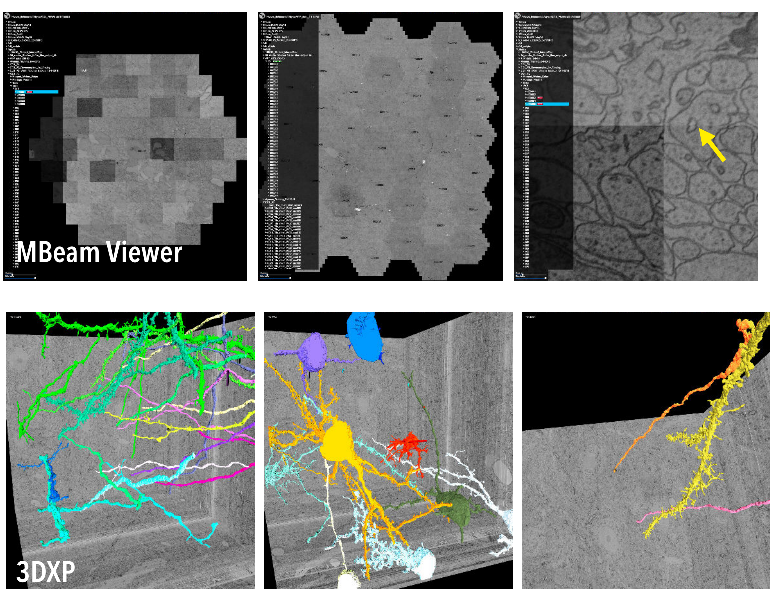
Open Data / Code / Results

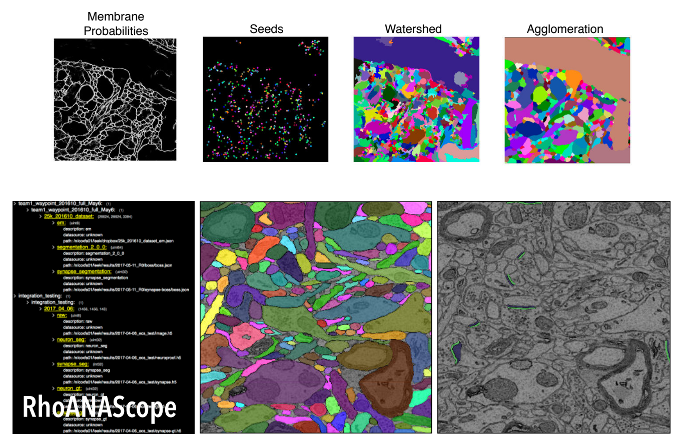
http://rhoana.org/guidedproofreading/

BUTTERFLY: Interactive Scalable Visualization for Connectomics









Query

```
/api/entity_feature?feature=synapse_parent&experiment=e&sample=s&dataset=d&channel=c&id=10
```

Response

```
{ "synapse_parent_pre": 888, "synapse_id": 10, "synapse_parent_post": 999 }
```

Neural Data Queries

Query

```
/api/entity_feature?feature=synapse_keypoint&experiment=e&sample=s&dataset=d&channel=c&id=10
```

Response

```
{ "y": 12800, "x": 12800, "z": 1700 }
```

D. Haehn, J. Hoffer, B. Matejek, A. Suissa-Peleg, A. K. Al-Awami, L. Kamentsky, F. Gonda, E. Meng, W. Zhang, R. Schalek, A. Wilson, T. Parag, J. Beyer, V. Kaynig, T. R. Jones, J. Tompkin, M. Hadwiger, J. W. Lichtman, and H. Pfister

Scalable Interactive Visualization for Connectomics

MDPI Informatics, 2017

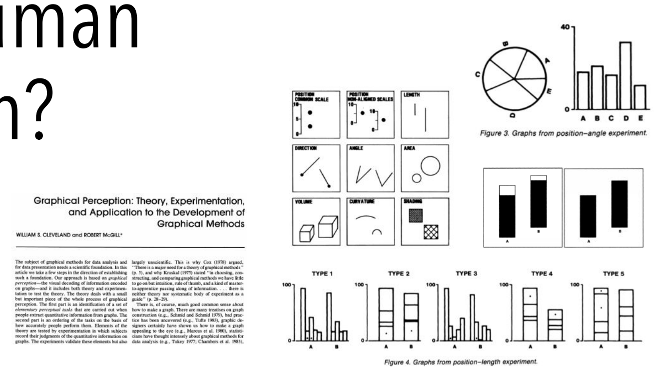
Daniel Haehn, James Tompkin, Hanspeter Pfister

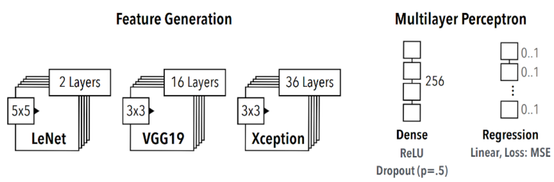
HARVARD
JOHN A. PAULSON
SCHOOL OF ENGINEERING
AND APPLIED SCIENCES

BROWN
Computer Science

Can CNNs model human graphical perception?

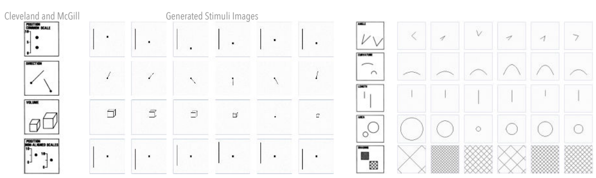
We replicate **Cleveland and McGill's 1984** human perception experiments with Convolutional Neural Networks.



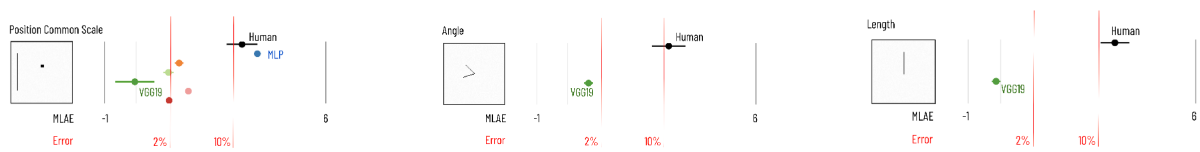


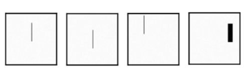
We evaluate **4 CNN architectures** with **2500+ configurations** (4.7 GPU years) on generated stimuli images.

Experiment 1: Elementary Perceptual Tasks



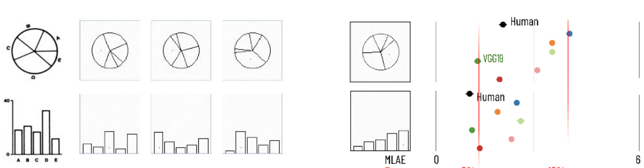
VGG19 performs much better than humans when estimating elementary perceptual visual stimuli.





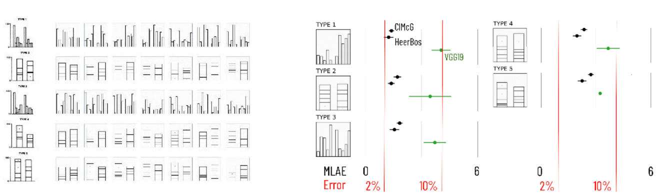
But slight visual **variations throw the networks off**.

Experiment 2: Position-Angle Experiment



Neural networks are able to estimate simple diagrams and, like humans, prefer bar charts over pie charts.

Experiment 3: Position-Length Experiment



Humans are better at comparing two different marked visual encodings. This **task seems too complex for CNNs** - even with increased training samples.

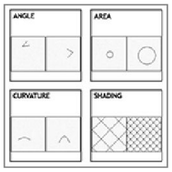
More experiments and results in our paper:

Evaluating 'Graphical Perception' with CNNs
in *IEEE Transactions on Visualization and Computer Graphics, 2018.*
Code / Data / Results available at https://bit.ly/machineperception

So can they..?

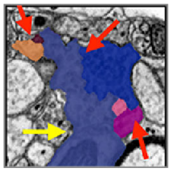
Not quite yet.

Are ResNet or CORNet the answer?



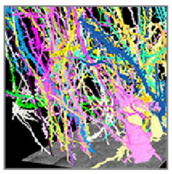
Evaluating 'Graphical Perception' with CNNs

IEEE Transactions on Visualization and Computer Graphics (IEEE VIS), 2018



Guided Proofreading of Automatic Segmentations for Connectomics

IEEE Computer Vision and Pattern Recognition (CVPR), 2018



Scalable Interactive Visualization for Connectomics

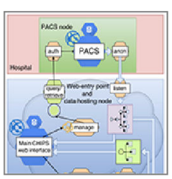
MDPI Informatics, 2017

Compresso: Efficient Compression of Segmentation Data For Connectomics

Medical Image Computing and Computer-Assisted Intervention (MICCAI), 2017

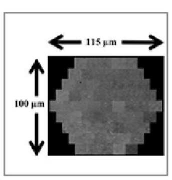
ICON: An Interactive Approach to train Deep Neural Networks for Segmentation of Neuronal Structures

IEEE International Symposium on Biomedical Imaging (ISBI), 2017



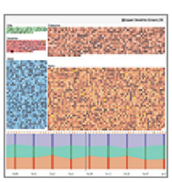
CHIPS-A Service for Collecting, Organizing, Processing, and Sharing Medical Image Data in the Cloud

VLDB Workshop on Data Management and Analytics for Medicine and Healthcare, 2017



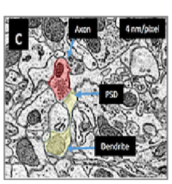
Automatic Neural Reconstruction from Petavoxel of Electron Microscopy Data

Microscopy and Microanalysis, 2016



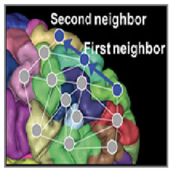
NeuroBlocks-Visual Tracking of Segmentation and Proofreading for Large Connectomics Projects

IEEE Transactions on Visualization and Computer Graphics (IEEE VIS), 2016



Imaging a 1 mm^3 Volume of Rat Cortex using a MultiBeam SEM

Microscopy and Microanalysis, 2016

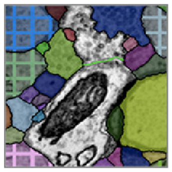


Altered Structural Brain Networks in Tuberous Sclerosis Complex

Cerebral Cortex, 2015

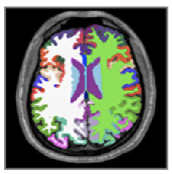
ChRIS-A web-based Neuroimaging and Informatics System for Collecting, Organizing, Processing, Visualizing and Sharing of Medical Data

IEEE Engineering in Medicine and Biology Society (EMBC), 2015



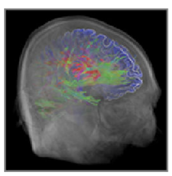
Design and Evaluation of Interactive Proofreading Tools for Connectomics

IEEE Transactions on Visualization and Computer Graphics (IEEE VIS), 2014



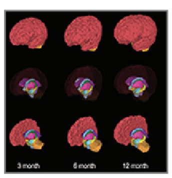
Slice:Drop - Collaborative Medical Imaging in the Browser

ACM SIGGRAPH Computer Animation Festival, 2013



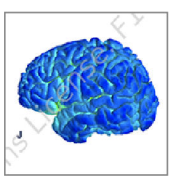
Neuroimaging in the Browser using the X Toolkit

Frontiers in Neuroinformatics, 2012



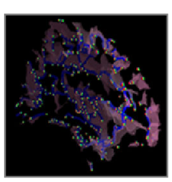
Regional Infant Brain Development: an MRI-based Morphometric Analysis in 3 to 13 month olds

Cerebral Cortex, 2012



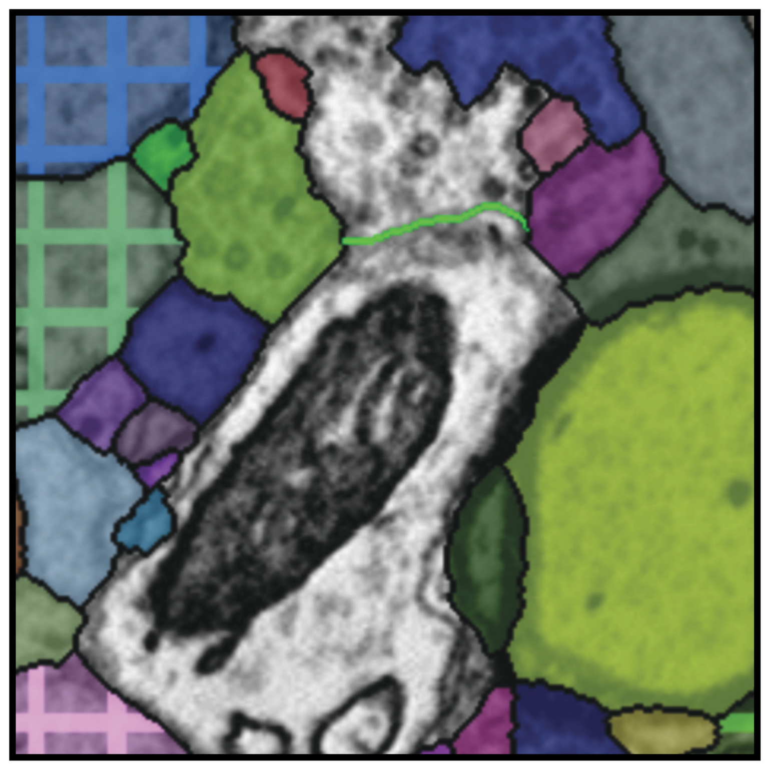
Mindboggle: Automated Human Brain MRI Feature Extraction, Labeling, Morphometry, and Online Visualization

Frontiers in Neuroinformatics, 2012

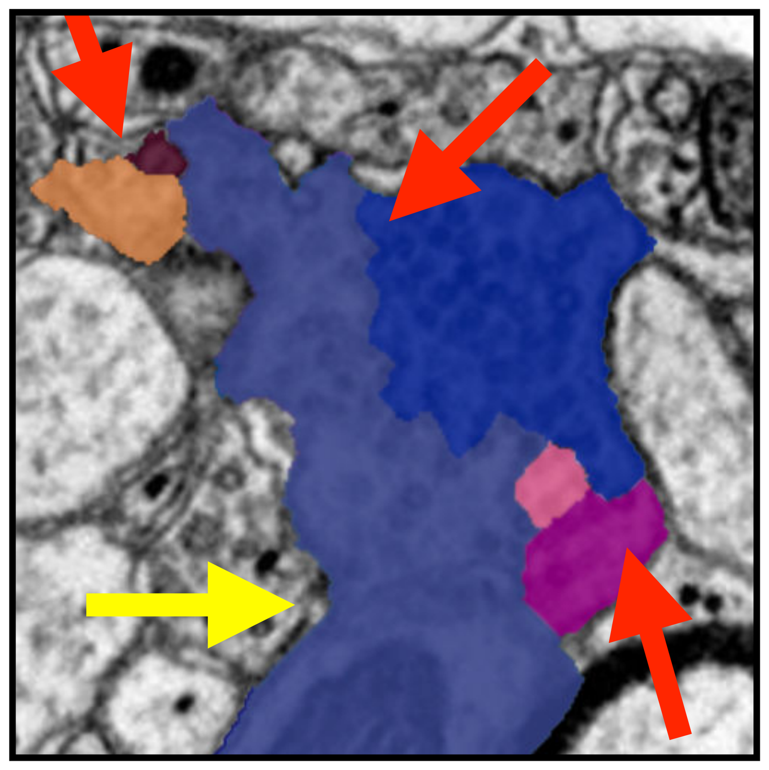


Mindboggle 2 interface: Online Visualization of Extracted Brain Features with XTK

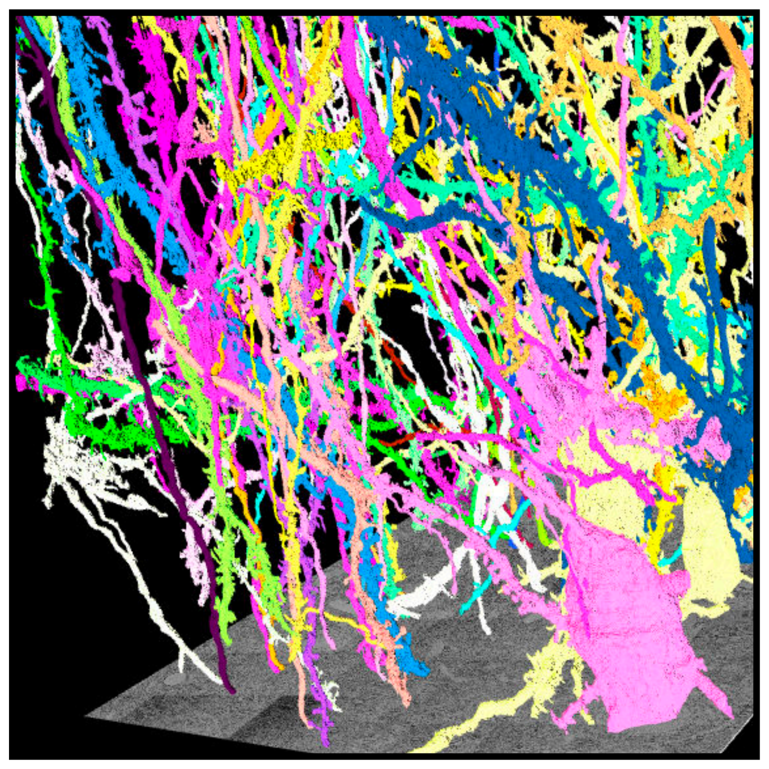
Frontiers in Neuroinformatics, 2012



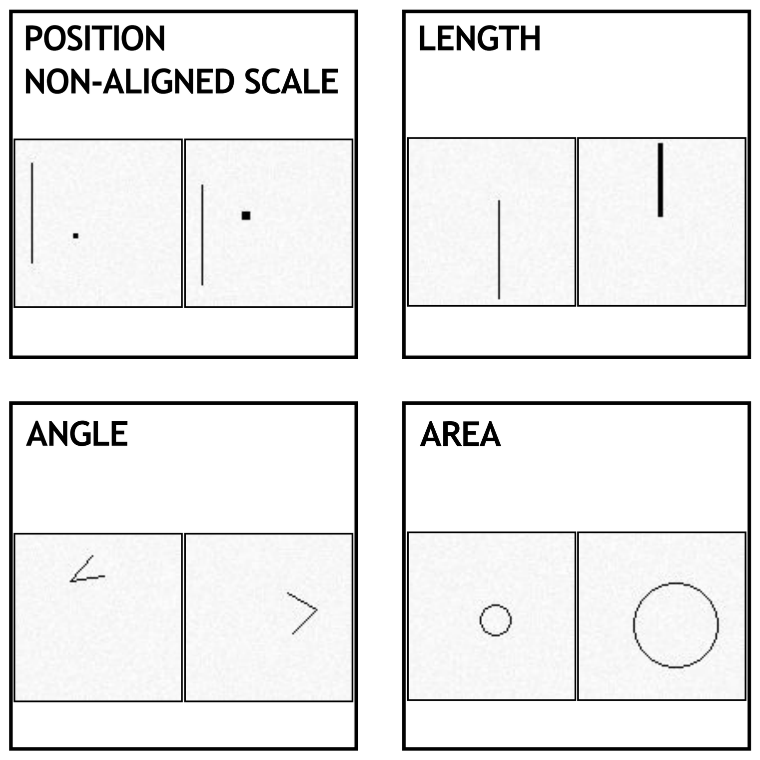
Interactive Correction of Neuron Segmentations



Guided Proofreading



Scalable Interactive Visualization for Connectomics



Graphical Perception of Convolutional Neural Networks

PhD Thesis Defense by Daniel Haehn

Analyzing Brain Connectivity and Computing Machine Perception

Artificial intelligence is loosely inspired by neuroscientific discoveries. However, existing methods are fragile and do not generalize well. In contrast, the brain allows humans to reliably recognize, extrapolate, and classify enormous amounts of stimuli—seemingly without effort. This difference in performance is likely the result of limited architectural correspondences between neurobiology and machine learning. With advances in computer science, my goal is to reduce the gap between natural and artificial intelligence: First, with bottom-up investigations for how visual computing methods can aid brain connectivity analysis, and second, exploring top-down how perceptual studies can increase the comprehension of machine learning models.

4 / 8 / 2019

1:30 pm

Isaacson Room

Smith Campus Center

Harvard University

More information and live stream: DANIELHAEHN.com/defense