

## Elliott M. Forney

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### Professional Statement

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I am a computer scientist who thrives on creating practical solutions to challenging problems in machine learning and data science. As a graduate student I have developed a strong foundation in computer science and an in-depth understanding of machine learning, artificial intelligence, computer vision and big data. As a researcher I have developed a specialization in the use of machine learning methods to analyze signals and time series. In particular, my recent work has focused on the use of deep convolutional and recurrent neural networks for modeling brainwave signals. I also have extensive industry experience as a Linux systems administrator and engineer and I have a passion for developing robust, high-performance software systems using open source technologies. I am currently seeking employment as a machine learning engineer and software developer and I am confident that my experience, drive and ambition will make me a valuable member of a team that is working toward innovative solutions to challenging problems.

### Education

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Doctorate (in progress), Computer Science Colorado State University	Jan 2012 - Present Anticipated completion: August 2017
Master of Science, Computer Science Colorado State University	Dec 2011
Bachelor of Science, Computer Science Double Major, General Mathematics Colorado State University	May 2006

### Research Assistantships

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*Research Assistant* *August 2011 - Present*  
*Colorado State University*  
*Brain-Computer Interfaces Laboratory*

- Explored the use of deep artificial neural networks, including convolutional and recurrent architectures, for analyzing and classifying signals and time-series, especially EEG signals.
- Acted as the principal software developer for the CSU Electroencephalography and Brain-Computer Interfaces Laboratory (CEBL<sub>3</sub>) platform, which is written primarily in Python.
- Investigated the use of state-of-the-art machine learning algorithms for solving problems in EEG analysis and BCIs, including feedforward neural networks, recurrent networks, echo state networks and self-organizing maps.

- Implemented standard machine learning algorithms, including ridge regression, logistic regression, regularized discriminant analysis, k-nearest neighbors, autoregressive models, L1 and L2-norm regularization, early-stopping and dropout regularization.
- Implemented search and optimization routines, including stochastic gradient descent, scaled conjugate gradients, resilient backpropagation, genetic algorithms, particle swarm optimization and a novel correlative optimization algorithm.
- Implemented signal processing algorithms, including power spectral densities using FFTs, continuous wavelet transforms, linear filters, interpolators and smoothers.
- Investigated source separation and decomposition algorithms, such as principal components analysis, independent components analysis and signal fraction analysis, for dimensionality reduction and artifact removal in EEG signals.
- Worked with undergraduate students to create a real-time interface for remotely controlling an ER1 robot and a simulated Baxter robot using a goal-directed P300-based BCI.
- Compared the performance of different EEG recording systems and BCIs among people without impairments in a laboratory environment versus participants with severe motor impairments in their home environments.
- Published and presented results in prominent journals and conferences.

*Student Scientist*

*Colorado State University*

*Brain-Computer Interfaces Laboratory*

*May 2010 - August 2010*

*May 2011 - August 2011*

- Implemented machine learning algorithms in the R programming language, including linear and quadratic discriminant analysis, feedforward and recurrent neural networks and principal components analysis.
- Developed custom software for stimulus presentation and the collection of EEG data.
- Assisted with over 20 EEG recording sessions for pilot BCI studies, including recording EEG from people with severe motor impairments.
- Performed initial exploratory analysis of EEG and BCI datasets, including comparisons of averaged event-related potentials and power-spectral densities and the effects of various filtering and referencing schemes.
- Contributed to the process of designing experiments, applying for institutional review board approval and writing research grants.
- This work partly contributed to our research group receiving a five-year research grant from the National Science Foundation.

## **Industry Experience**

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*UNIX Systems Administrator*

*Colorado State University Computer Science Department*

*May 2008 - Jan 2012*

- Managed approximately 300 workstations and servers running various flavors of Linux and UNIX in a scientific computing and research oriented environment.

- Developed custom applications for monitoring, alerting and management of shared resources, including programs for managing disk quotas, runaway processes and parallel distribution of system configurations and updates.
- Installed, configured and updated numerous software applications, including NFS, NIS, Apache, MySQL, Drupal, Wordpress, MATLAB, Elcipse, Android SDK, ffmpeg, CUDA and custom builds of R and NumPy linked against Intel's Math Kernel Libraries.
- Troubleshot various software and hardware problems for students, faculty and professors in the computer science department.

*UNIX Systems Administrator & Systems Analyst*  
*West Corporation*

*July 2006 - July 2007*

- Worked with a small team to manage several thousand servers running various flavors of Linux and UNIX in a high-volume, high-availability, production environment.
- Developed custom software for maintenance, monitoring and alerting, including modules for the Big Brother monitoring system and automated support ticket generation.
- Provided 2nd tier support for numerous public and proprietary software products, such as VoiceGenie, Nuance Text-To-Speech & Automated Speech Recognition, F5 BigIP and a number of in-house software solutions.
- Installed, updated and configured software and operating systems with minimal downtime.
- Performed security audits and implemented security and privacy safeguards.

## **Full-Length Papers**

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- Learning Deep Representations of EEG Signals in Mental-Task Brain-Computer Interfaces using Convolutional and Recurrent Networks. Elliott M. Forney (2017) Preliminary PhD Exam. Department of Computer Science, Colorado State University, Fort Collins, CO.
- Echo State Networks for Modeling and Classification of EEG in Mental Task Brain-Computer Interfaces. Forney, E., Anderson, C., Gavin, W., Davies, P., Roll, M., Taylor, B. (2015) Technical Report, Department of Computer Science, Colorado State University, Fort Collins, Colorado.
- Representing and Classifying EEG Signals in Mental Task Brain-Computer Interfaces. Elliott Forney (2013) Research Exam. Department of Computer Science, Colorado State University, Fort Collins, CO.
- Classification of EEG During Imagined Mental Tasks by Forecasting with Elman Recurrent Neural Networks. Forney, E. and Anderson, C. In *Proceedings of the International Joint Conference on Neural Networks*, July 31–August 5, 2011. pp. 2749–2755.
- Reliable identification of mental tasks using time-embedded EEG and sequential evidence accumulation. Anderson, C., Forney, E., Hains, D., Natarajan, A. *Journal of Neural Engineering*, April 2011, vol. 8, no. 2, 025023.
- EEG character identification using stimulus sequences designed to maximize minimal hamming distance. Fukami, T., Shimada, T., Forney, E., Anderson, C. *Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, August 28–September 1, 2012. pp. 1782–1785. 2012.

- Critical issues in state-of-the-art brain-computer interface signal processing. Krusienski, D., Grosse-Wentrup, M., Galan, F., Coyle, D., Miller, K., Forney, E., Anderson, C. *Journal of Neural Engineering*, April 2011, vol. 8, no. 2, 025002.
- Electroencephalogram Classification by Forecasting with Recurrent Neural Networks. Elliott Forney (2011) Masters Thesis, Department of Computer Science, Colorado State University, Fort Collins, CO. 2011.

## Short Papers

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- Detecting P300 ERPs with Convolutional Networks. Elliott M. Forney, Charles W. Anderson, Patricia L. Davies, William J. Gavin, Marla C. Roll. *Proceedings of the International Brain-Computer Interface Meeting*, Asilomar California, May 30<sup>th</sup> – June 3<sup>rd</sup>, 2016. Graz University of Technology Publishing House.
- CEBL<sub>3</sub>: A New Software Platform for EEG Analysis and Rapid Prototyping of BCI Technologies. Elliott M. Forney, Charles W. Anderson, William J. Gavin, Patricia L. Davies, Marla C. Roll, Igor Ryzhkov, Fereydoon Vafaei. *Proceedings of the International Brain-Computer Interface Meeting*, Asilomar California, May 30<sup>th</sup> – June 3<sup>rd</sup>, 2016. Graz University of Technology Publishing House.
- Brain Computer Interface Classifier Parameters Are Influenced by Practice: Results from a P300 Speller. The, K., Taylor, B., Crasta, J., Lin, M.H., Forney, E., Anderson, C., Davies, P., and Gavin, W. *Proceedings of the Society of Psychophysiological Research (SPR)*, 2014.
- A Stimulus-Free Brain-Computer Interface Using Mental Tasks and Echo State Networks. Forney, E., Anderson, C., Gavin, W., and Davies, P. In *Proceedings of the Fifth International Brain-Computer Interface Meeting: Defining the Future*, June 3 - 7, 2013. Graz University of Technology Publishing House.
- The N100 of Averaged ERPs Predicts LDA Classifier Success on an Individual Basis. Taylor, B., Forney, E., Gavin, W., Anderson, C., and Davies, P. In *Proceedings of the Fifth International Brain-Computer Interface Meeting: Defining the Future*, June 3 - 7, 2013. Graz University of Technology Publishing House.
- A Comparison of EEG Systems for Use in P300 Spellers by Users With Motor Impairments in Real-World Environments. Forney, E., Anderson, C., Davies, P., Gavin, W., Taylor, B., and Roll M. In *Proceedings of the Fifth International Brain-Computer Interface Meeting: Defining the Future*, June 3 - 7, 2013. Graz University of Technology Publishing House.

## Select Presentations

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- EEG Signal Classification in Asynchronous BCIs A Journey from Time Embedding to Convolutional Networks. Presented at the Workshop on Deep Learning and other Machine Learning and Signal Processing Methods for Analyzing EEG in BCI Paradigms at the International BCI Meeting, June 1<sup>st</sup>, 2016, Pacific Grove, California. *Invited Speaker*.
- Convolutional Networks for EEG Signal Classification in Non-Invasive Brain-Computer Interfaces. Presented at the Front Range Neuroscience Group (FRNG) Annual Meeting, December 9<sup>th</sup>, 2015, Fort Collins, Colorado. *Poster*.

- Brain-Computer Interfaces: Demonstrations and Discussions of Applications. Anderson, C., Davies, P., Roll, M., Gavin, W., Forney, E. and Heffern, C. Presented at the Rehabilitation Engineering and Assistive Technology Society of North America (RESNA) Annual Conference, June 13<sup>th</sup>, 2015, Denver, Colorado. *Oral Presentation and Live Demonstration of a BCI system.*
- CEBL<sub>3</sub>: A Modular Platform for EEG Signal Analysis and Real-Time Brain-Computer Interfaces. Forney, E. and Anderson, C. Presented at the Front Range Neuroscience Group (FRNG) Annual Meeting, December 10<sup>th</sup>, 2014, Fort Collins, Colorado. Also presented at the Colorado State University Graduate Student Showcase, February 20<sup>th</sup>, 2015, Fort Collins, Colorado. *Poster.*
- A Direct Brain-Computer Interface for Multimedia and Environmental Controls. Forney, E., Anderson, C., Gavin, W. and Davies, P. Presented at the Colorado State University Ventures Annual Meeting, April, 2015. Fort Collins, Colorado. *Selected Student Speaker.*
- A Brief Introduction to Brain-Computer Interfaces. Forney, E. Presented to a graduate course on human-computer interfaces, April, 2015. Department of Technical Journalism, Colorado State University, Fort Collins, Colorado. Also presented to a graduate course on assistive technology, April 10<sup>th</sup>, 2014. Department of Occupational Therapy, Colorado State University, Fort Collins, Colorado. *Guest Lecture.*
- A Stimulus-Free Brain-Computer Interface using Mental Tasks and Echo State Networks. Forney, E., Anderson, C., Gavin, W. and Davies, P. Presented at The International BCI Meeting, June 3-7, 2013, Pacific Grove, California. *Poster.*
- Classification of EEG During Imagined Mental Tasks by Forecasting with Elman Recurrent Neural Networks. Forney, E. and Anderson, C. Presented at the International Joint Conference on Neural Network (IJCNN), August 5<sup>th</sup>, 2011, San Jose, California. *Selected student Speaker.*
- Modeling and Classification of EEG by Forecasting with Recurrent Artificial Neural Networks. Forney, E. and Anderson, C. Presented at the Front Range Neuroscience Group (FRNG) Annual Meeting, December 7<sup>th</sup>, 2011, Fort Collins, Colorado. *Selected student speaker.*
- Modeling and Classification of EEG using Recurrent Neural Networks. Forney, E. and Anderson, C. Presented at the Fourth International BCI Meeting, May 31st - June 4<sup>th</sup>, 2010, Asilomar California. *Poster.*
- $\log |\hat{f}\left(\frac{z^{17}}{z^{15}-1}\right)|$  (2015), Singular Figures (2012), Raytracer (2011), Brainripples (2010), Elliott Forney, *Artwork accepted to the CSU juried Art and Science Exhibition.*

## Software Projects

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- **CEBL<sub>3</sub>** (Colorado EEG and BCI Laboratory): A modular, real-time Brain-Computer Interface system written primarily in Python and C. CEBL<sub>3</sub> is designed to support all phases of Brain-Computer Interface (BCI) research and development and includes a variety of standard and cutting edge features for signal processing, machine learning, visualization and a fully functional graphical user interface for real-time BCI applications.  
<https://github.com/idfah/cebl>
- **Rml** (R Machine Learning): A collection of machine learning modules written in the R programming language and derived from my Master's research. Rml currently focuses on artificial neural networks, including feedforward, recurrent and echo state networks. Current optimization methods include stochastic gradient descent, resilient backpropagation,

scaled-conjugate gradients and a novel variant of ALOPEX.

<http://www.elliottforney.com/projects/Rml>

- **BCibots:** As part of my graduate research in Brain-Computer Interfaces, I worked with a small team to develop novel interfaces for controlling robotics platforms using our CEBL BCI software. These interfaces include methods for remotely driving a robotic cart built using the ER1 robotics platform as well as methods for controlling a virtual Baxter robot.  
<http://www.elliottforney.com/projects/bcibots>
- **badger:** A machine learning and matrix framework for C and C++ that makes use of highly optimized kernels for both NVIDIA's GPU's (using CUDA) and Intel CPU's (using OpenMP and SSE). This library currently supports feedforward networks as well as a number of tuned matrix and vector operations. <https://github.com/idfah/badger>
- **goofs:** A distributed and fault-tolerant file system that is modeled after Google's distributed file system. Goofs was written in Java for a graduate course on distributed computing and supports distributed reads, writes, appends and passive replication. <https://github.com/idfah/goofs>
- **sshall:** Born out of my needs as a systems administrator, sshall is a simple but flexible tool for executing remote commands across multiple hosts. sshall works well with shell pipelines and allows parallel execution. <https://github.com/idfah/sshall>
- **raytrace:** A multi-threaded Java application for rendering 3D scenes using raytracing, written for a graduate course on computer graphics. This project includes a graphical user interface and fully supports, spheres, polygons, cylinders, specular, diffuse and ambient lighting, reflections, refractions, partially opaque atmosphere and a thin-lens model.  
<https://github.com/idfah/raytrace>
- **scimus:** A 3d virtual science museum written from scratch using C and OpenGL. Scimus is a demonstration of OpenGL technologies and includes an extensive framework for first-person navigation of 3D virtual worlds. <https://github.com/idfah/scimus>

## Honors and Awards

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- **Student Travel Award.** I received this award, funded by the NSF and NIH, to attend and present my research at the 2016 International Brain-Computer Interfaces Meeting.
- **Artificial Intelligence and Evolutionary Computation Fellowship.** I received this fellowship award from the Colorado State University Computer Science Department in 2015 for excellence in research in the fields of machine learning and brain-computer interfaces.
- **Graduate School Excellence Award.** I received this award for my poster presentation titled "CEBL3: A Modular Platform for EEG Signal Analysis and Real-Time Brain-Computer Interfaces" presented at the 2015 Colorado State University Graduate Student Showcase.
- **CSU Ventures Competition Finalist.** I received this award for my selected oral presentation titled "BCI Player: A Direct Brain-Computer Interface for Multimedia and Environmental Controls" at the 2015 CSU Ventures Competition.
- **Student Art Award.** I received this award for my artwork titled "Energy" that I presented at the 2014 Front Range Neuroscience Group (FRNG) annual meeting in Fort Collins, Colorado.

- **Best Overall Poster Award.** I received this award for my poster presentation titled “A Stimulus-Free Brain-Computer Interface using Mental Tasks and Echo State Networks” presented at the 2013 International BCI Meeting in Asilomar, California.
- **Honorable Mention.** I received this award for my artwork titled “Singular Figures” presented at the 2012 juried CSU Art and Science Exhibition in Fort Collins, Colorado.
- **Best Student Presentation Award.** I received this award for my oral presentation titled “Modeling and Classification of EEG by Forecasting with Recurrent Artificial Neural Networks” presented at the 2011 Front Range Neuroscience Group (FRNG) annual meeting in Fort Collins, Colorado.
- **1<sup>st</sup> Place in Computer Science Competition.** I received this award for my performance in the Western Nebraska Interscholastic Competition while I was a senior in high school in 2000.

## Professional Associations

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- Selected member and former officer of the CSU Beta Chapter of The Upsilon Pi Epsilon ( $\Upsilon\Pi E$ ) Computer Science Honor Society.
- Member of the Brain-Computer Interfaces Society.
- Member of the CSU Molecular, Cellular and Integrative Neuroscience (MCIN) group.
- Reviewer for various journals and conferences, including The International Joint Conference on Neural Networks, Engineering Applications of Artificial Intelligence, IEEE Symposium Series on Computational Intelligence, IEEE International Conference on Tools with Artificial Intelligence, IEEE Transactions on Control Systems and Technology, Connection Science and IEEE Transactions on Neural Networks and Learning Systems.