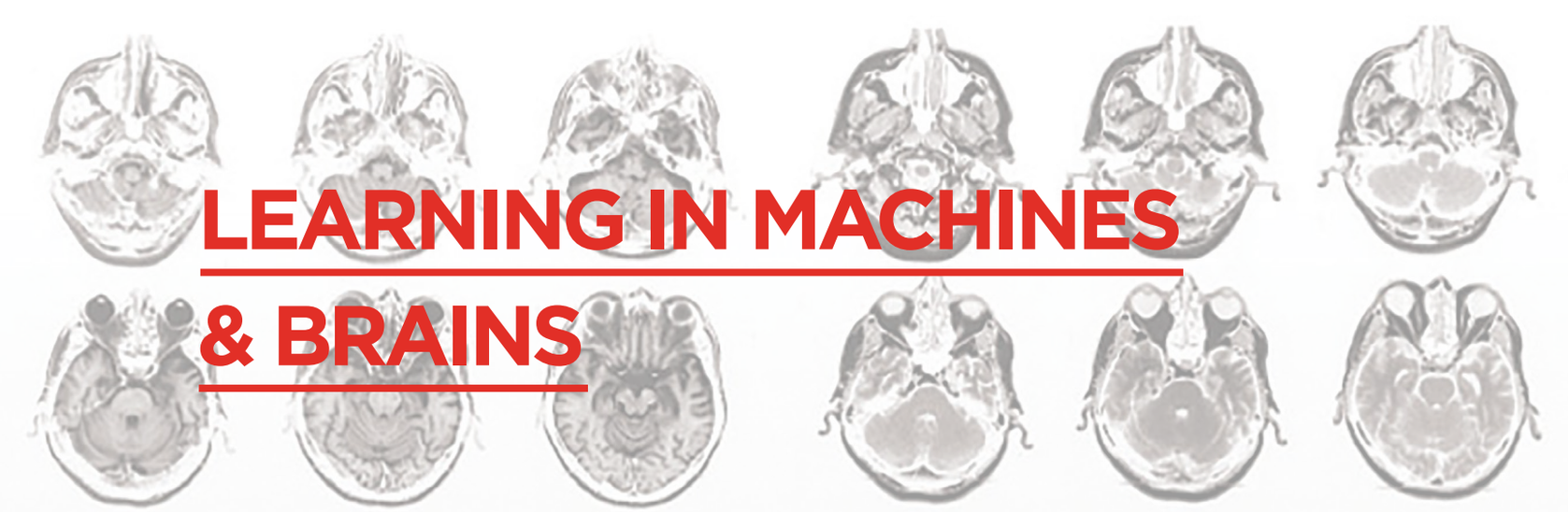

# LEARNING IN MACHINES & BRAINS

**Seeks to contribute to the understanding of the computational and mathematical principles that enable intelligence through learning, be it in brains or in machines.**

The December 2016 program meeting in Barcelona focused on deep learning, particularly generative adversarial networks and biologically plausible learning. As a primary research direction that underlies the investigations of the program, deep learning examines algorithms that uncover multiple levels of representation for observed data. A second meeting, held in Paris, in partnership with Inria and Collège de France, after the International Conference on Learning Representations, focused on deep learning and neuroscience. The meeting covered topics such as deep learning models as models for the brain and how the brain might use learning algorithms such as backpropagation.

In August 2016 the program hosted its largest Deep Learning Summer School to date, with more than 600 applicants from around the world, of which 230 participated, including graduate students, industrial engineers and researchers.

The program hosted two workshops this year. A workshop on Medical Imaging and Computer Vision was held in Amsterdam in October 2016. Program members also held a joint workshop on Energy Materials Discovery in May 2017 with our Bio-inspired Solar Energy program. The theme was the use of high-throughput machine learning to accelerate the discovery of materials and molecules, in an effort to bridge the communication divide between machine learning experts, computational chemists and materials engineers.

Several additional start-up companies were created this year by program members and their students, including Structura Biotechnology in Toronto, and Element AI, Lyrebird and Bolter in Montreal. These start-ups all take advantage of the advances in deep learning spearheaded by the program in recent years.

## RESEARCH HIGHLIGHTS

Senior Fellow **Max Welling** (University of Amsterdam) and colleagues applied a deep learning technique, scattering networks, to the analysis of Alzheimer's disease from brain MRI data. The study showed that in a semi-supervised learning setting, it is possible to predict, with 83 per cent certainty, whether a patient diagnosed with "mild cognitive impairment" will develop Alzheimer's disease. This approach achieves greater accuracy than current competing methods.

- Adela T, Cohen T, Caan M, **Welling M**. 2017. 3D scattering transforms for disease classification in neuroimaging. NeuroImage-Clin. 14: 506–517.

A great deal of progress was made this year in linking backpropagation, the main algorithm used to train neural networks in deep learning, and the brain. Work by Program Co-Director **Yoshua Bengio** (Université de Montréal) uncovered new theorems and simulation results that bring us closer to a plausible explanation of how the brain could learn in a similar way to backpropagation. This multidisciplinary work has been influenced by many discussions with CIFAR Advisor **Geoff Hinton** (University of Toronto and Google) and collaborations with **Walter Senn** and **Joao Sacramento**, who participated in this year's Deep Learning & Neuroscience workshop.

- Scellier B, **Bengio Y**. 2017. Equilibrium propagation: Bridging the gap between energy-based models and backpropagation. Front Comp Neurosc. 11: 24.

**Nando de Freitas** (University of Oxford) and collaborators revisited and expanded on ideas introduced in the 1990s by the Bengio brothers, inspired by the fact that evolution has learned the learning procedure for brains. Machine learning has made advances in moving from hand-designed features to learned features; however, optimization algorithms are still currently designed by hand. This paper describes how the design of an optimization algorithm can be cast as a learning problem and allow for the automatization of algorithm learning using recurrent neural networks. These learned

# AT A GLANCE

**FOUNDED:** 2004

**MOST RECENT RENEWAL:** 2014

**PROGRAM DIRECTORS:** Yoshua Bengio, Université de Montréal, and Yann LeCun, New York University and Facebook AI Research

**FELLOWS, ADVISORS AND CIFAR AZRIELI GLOBAL SCHOLARS:** 41

**INSTITUTIONS REPRESENTED:** 27, in 7 countries

**FIELDS AND SUBFIELDS REPRESENTED:** computer science, including artificial intelligence and machine learning; neuroscience; bioinformatics and computational biology

**MEETINGS:** 2; in Barcelona, Spain, and Paris, France

**RELEVANT KNOWLEDGE USERS:** industry, including entrepreneurs and start-ups, with interests in deep learning-based technologies and applications

**PARTNERS:** Brain Canada Foundation through the Canada Brain Research Fund | Facebook | Google Inc. | Inria

**SUPPORTERS:** Céline and Jacques Lamarre

**TO LEARN MORE:** www.cifar.ca/research/learning-in-machine-and-brains/

algorithms outperform hand-designed competitors and have some success generalizing to other tasks.

- Andrychowicz M, **de Freitas N.**, et al. 2016. Learning to learn by gradient descent by gradient descent. In the Annual Conference on Neural Information Processing Systems (NIPS).

### Other Notable Publications and Outputs

- Shafaei A, Little J, Schmidt M. 2016. Play and learn: Using video games to train computer vision models. arXiv preprint arXiv: 1608.01745.
- Ren M, Liao R, Urtasun R, Sinz FH, Zemel RS. 2017. Normalizing the normalizers: Comparing and extending network normalization schemes. ICLR 2017.
- Punjani A, Rubinstein J, Fleet DJ, Brubaker M. 2017. cryoSPARC: Algorithms for rapid unsupervised cryo-EM structure determination. Nat Methods. 14(3): 290-296.

## IDEAS EXCHANGE

Program fellows led activities over the year that engaged clinical, policy, industry and academic leaders in discussions about machine and deep learning in medical imaging. In October, a Deep Learning for Medical Imaging Workshop was held in Amsterdam that explored how deep learning is affecting medical imaging. In April a roundtable on Medical Imaging and Machine Learning was held in Toronto. Senior Fellow **Max Welling** presented examples of deep learning surpassing human performance, and discussed implications, challenges and benefits for the health care sector.

## GLOBAL ACADEMY

Two new CIFAR Azrieli Global Scholars joined the program for a two-year term, as part of the inaugural cohort appointed in 2016/2017. **Graham Taylor** (University of Guelph) and **Joel Zylberberg** (University of Colorado) both presented their work at the December 2016 program meeting.

The program held its largest-ever annual summer school on deep neural networks in Montreal on August 1-7, 2016. Fellow Aaron Courville and Program Co-Director **Yoshua Bengio** (both Université de Montréal) organized the summer school.

**As an example of a new type of optimization algorithm, an algorithm designed by Senior Fellow Nando de Freitas combined a the photo at the left with the painting style on the right and produced the centre image (image courtesy of the researcher).**