



Session Traitements

Architectures neuronales

ARE DEEP NEURAL NETWORKS BIO-INSPIRED AND WHY
NEUROMORPHISM IS IMPORTANT FOR THE FUTURE OF AI

Martial Mermillod

LPNC

WORKSHOP

L'Intelligence Naturelle au coeur
des enjeux de l'Intelligence Artificielle



NeuroCoG
Unité Grenoble Alpes

UNIVERSITÉ
GRENOBLE
Cognition



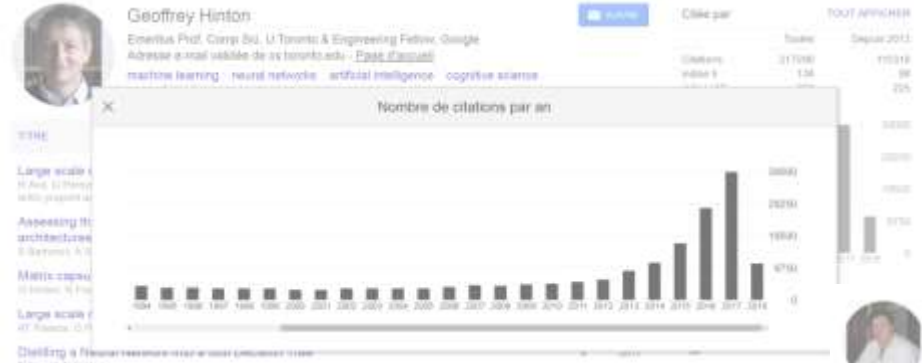
Deep Learning: The New Revolution of AI

Krizhevsky, A., Sutskever, I., & Hinton, G. E. (2012). Imagenet classification with deep convolutional neural networks. In Advances in neural information processing systems (pp. 1097-1105).

Why on December 2012 ?

3 factors:

1. Deep Neural Networks ready for a while
2. GAFA -> BIG DATA
3. GPU -> convolution/pooling

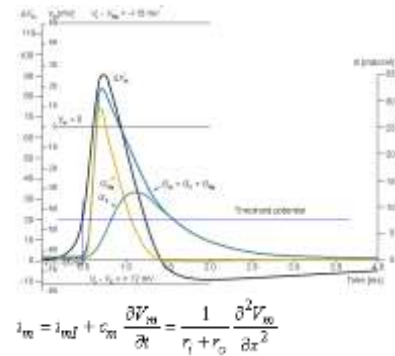
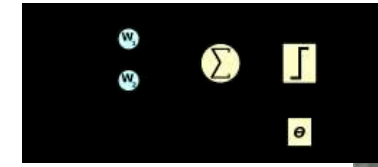
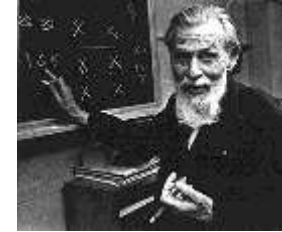




Question: To what extent Deep Learning is brain-inspired?

The fundamental component of human mind:
From neurons to the psyché.

McCulloch, W. S., & Pitts, W. (1943). A logical calculus of the ideas immanent in nervous activity. *The bulletin of mathematical biophysics*, 5(4), 115-133.



Hodgkin, A. L., & Huxley, A. F. (1952). A quantitative description of membrane current and its application to conduction and excitation in nerve. *The Journal of physiology*, 117(4), 500-544

Hebb, D. O. (1949). *The organization of behavior: A neuropsychological theory*. Wiley, New York



$$w_{ij} = \frac{1}{p} \sum_{k=1}^p x_i^k x_j^k,$$



Rosenblatt, F. (1958). The perceptron: a probabilistic model for information storage and organization in the brain. *Psychological review*, 65(6), 386.



From Multi-Layer Perceptron (MLP) to Deep Neural Networks (DNN)

Geoffrey Hinton
(1947-20XX) : Psychology & Computer Science,
University of Toronto. Parallel Distributed
Processing Group.



David Everett Rumelhart
(1942-2011) : Psychology, UCSD and Stanford
University. Parallel Distributed Processing Group.

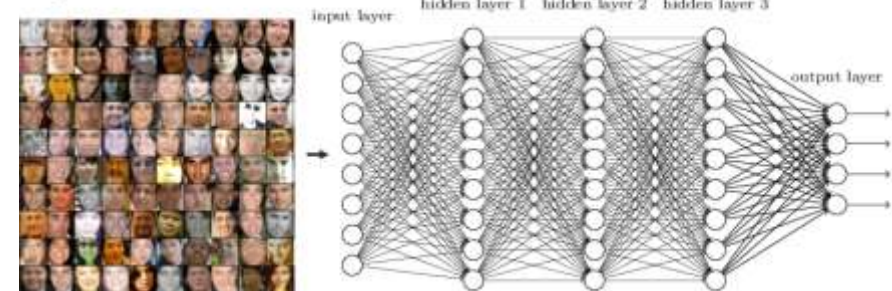


James McClelland
(1948-20XX) : Psychology & Cognitive Science, Stanford
University. Parallel Distributed Processing Group.

Deep neural
networks learn
hierarchical feature
representations



LeCun, Y., Bengio, Y., & Hinton, G. (2015). Deep learning. *Nature*, 521(7553), 436.





Ok, Neural Networks are coming from Cognitive Sciences, but Is Deep Neural Network Still bio-inspired?

iEEG Data with humans

Kuzovkin, I., Vicente, R., Petton, M., Lachaux, J. P., Baciú, M., Kahane, P., ... & Aru, J. (*in press*). Activations of Deep Convolutional Neural Network are Aligned with Gamma Band Activity of Human Visual Cortex. *Nature Communication Biology*.

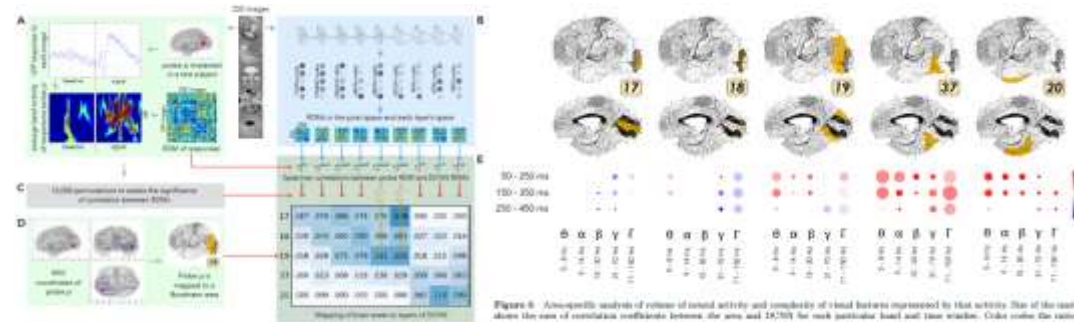
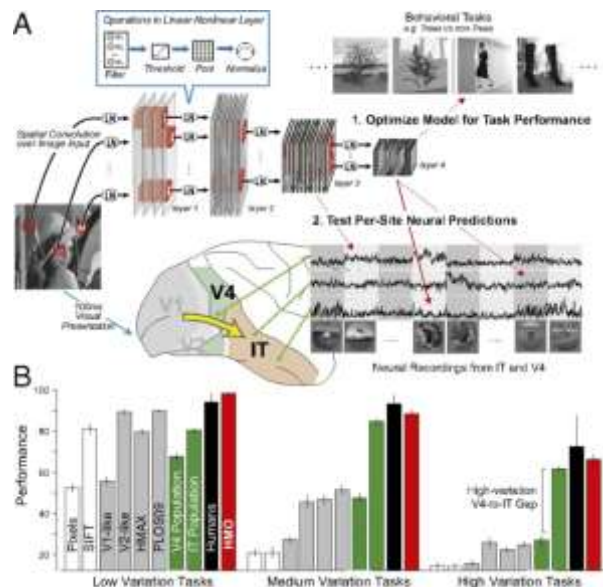


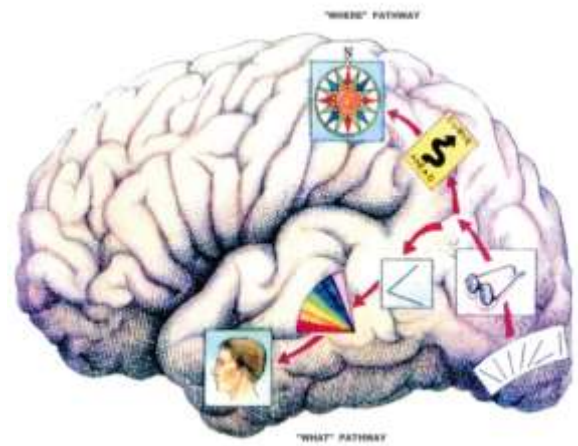
Figure 8. Anisotropic analysis of volume of neural activity and complexity of a local feature set expressed by that activity. This of the matrix shows the size of correlation coefficients between the area and DNN for each particular band and time window. Colors encode the ratio of complex visual features to single visual features, i.e. the comparison between the activity that correlates with the higher layers (alpha, beta, gamma) of DNN to the lower layers (theta, delta). Intuitive not means that the activity was correlating more with the activity of higher layers of DNN, while the intensive blue indicates the dominance of correlation with the lower ones. If the color is blue it will be the activation of both lower and higher layers of DNN were correlating with the brain responses in approximately equal proportions.



Yamins, D. L., Hong, H., Cadieu, C. F., Solomon, E. A., Seibert, D., & DiCarlo, J. J. (2014). Performance-optimized hierarchical models predict neural responses in higher visual cortex. *Proceedings of the National Academy of Sciences*, 111(23), 8619-8624.



Ok, but is Brain-Inspired Technology still required for future AI?



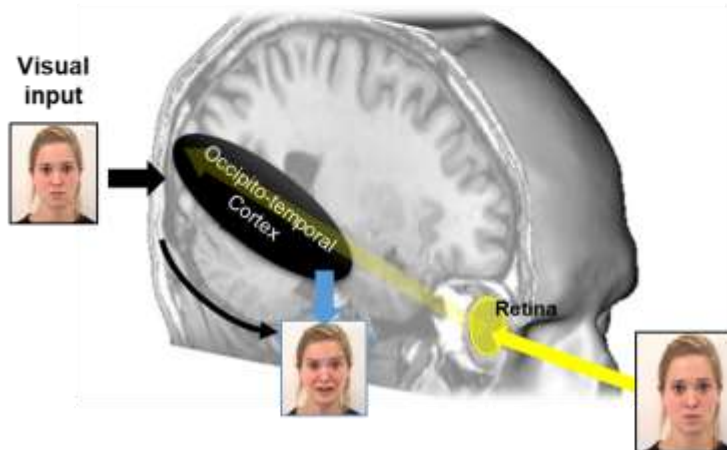
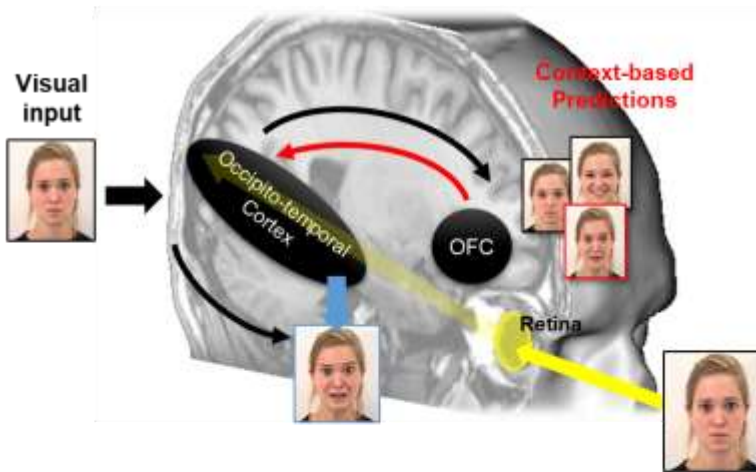
Gestalt processes and top-down expectations urgently required!

Koffka, K. (1922). Perception: an introduction to the Gestalt-Theorie. *Psychological Bulletin*, 19(10), 531.

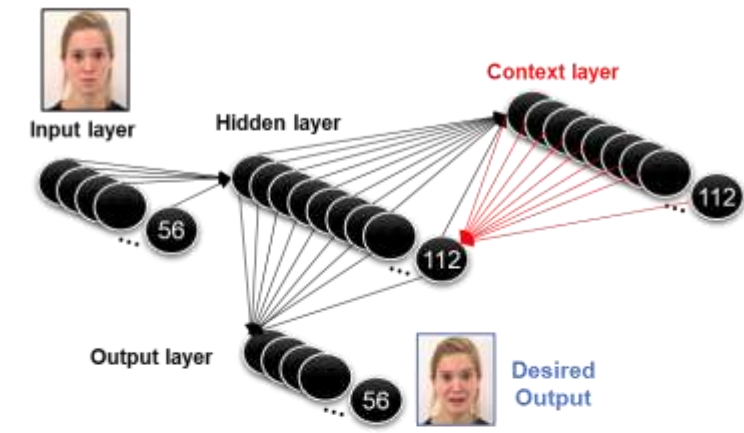


Example: Bio-inspired Predictive Brain

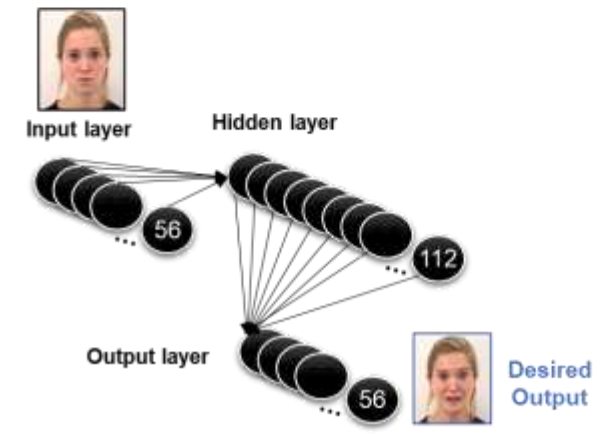
Mermillod et al. (in revision). The Importance of Recurrent Top-Down Synaptic Connections for the Anticipation of Dynamic Emotional Expressions. *Neural Networks*.



Simple Recurrent Network (SRN)



Multi-layer Perceptron (MLP)





Perspective: Beyond Turing-Von Neumann machine

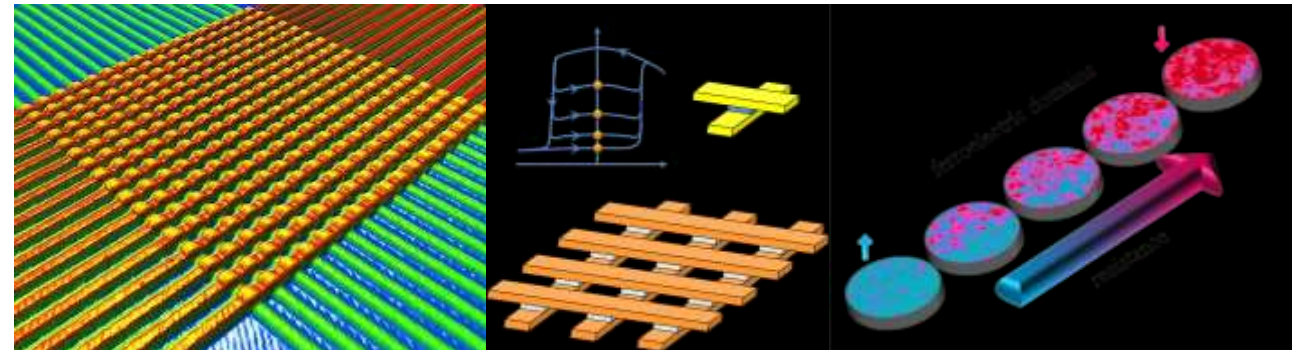
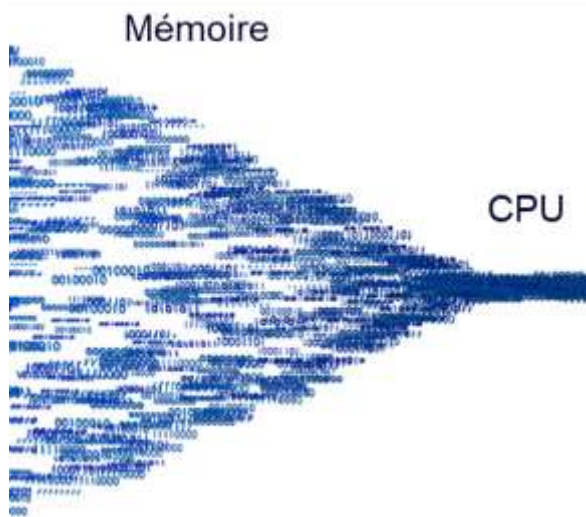
Torrejon, J., Riou, M., Araujo, F. A., Tsunegi, S., Khalsa, G., Querlioz, D., ... & Kubota, H. (2017). Neuromorphic computing with nanoscale spintronic oscillators. *Nature*, 547(7664), 428.

Turing-Von Neumann Machine

- CPU \neq Memory
- CPU serial processes

Neural Networks

- CPU = Memory
- Parallel and distributed processes



The Importance of Training for a New Generation of Researcher in AI !



Fei-Fei Li
 Professor of Computer Science, Stanford University; Chief Scientist of AI/ML, Google Cloud

Known for:
 Computer vision
 Machine learning
 Artificial intelligence
 Cognitive neuroscience

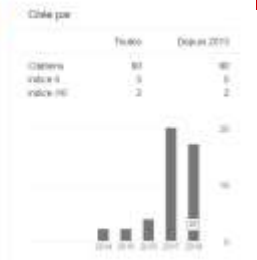


10 Professor positions in Cognitive Systems and Materials, to break new scientific ground



Panqu Wang
 TuSimple
 Adresse e-mail valide de acad.edu - Page d'accueil
 Object Recognition Cognitive Modeling

STATE	CITED PAPER	ANNÉE
Understanding convolution for semantic segmentation	48	2017
Are face and object recognition independent? A neurocomputational modeling exploration	17	2018
A computational model of the development of hemispheric asymmetry of face processing	8	2013
Encoding space with deep learning	7	2015
Modeling the contribution of central versus peripheral vision in scene, object, and face recognition	5	2016
Basic Level Categorization Facilitates Visual Object Recognition	4	2015
Experience matters: Modeling the relationship between face and object recognition	4	2014
Central and peripheral vision for scene recognition: A neurocomputational modeling exploration	3	2017
Modeling the Object Recognition Pathway: A Deep Hierarchical Model Using Gravitic Fields	3	2015



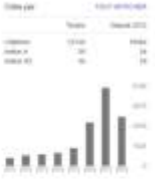
- Coauthors:**
- Carlson W. Crone
 - Yi Ma
 - Robert Sengco
 - Paul Sengco



Yann LeCun
 Postdoc at Hinton's lab.
 Developed DJVu format.
 Father of Convolutional Neural Networks and Optical Character Recognition (OCR).
 Proposed bio inspired ML methods like "Optimal Brain Damage" a regularization method.
 LeNet-5 is now state-of-the-art in artificial vision.

Georges Haasakis
 Université de Bourgogne - Université de Bourgogne

Issues Facing the Trucking Industry



Project	Start	End
Management Learning through deep reinforcement learning	2016	2016
Expanding the game of Go with deep neural networks and tree search	2016	2016
Planning with hippocampal-inspired context-regularized sparse exploration	2016	2016
Discovering useful symbolic memory with combinatorial	2016	2016
When face is not: World experience-rich perceptual-computational gap in humans	2016	2016
The fusion of memory, reasoning, planning, and the brain	2016	2016
Using cy integration to understand the neural basis of episodic memory	2016	2016
Mastering the game of go without human knowledge	2016	2016
Highly complex: using a neural network to estimate optimal memory	2016	2016
The construction system of the brain	2016	2016
From Model to Brain: The neural organization of behavior for systems in humans	2016	2016
Developing neural algorithms for the human hippocampus	2016	2016
Training the emergence of contextual knowledge during human decision-making	2016	2016

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