Deep generative models

Apéritif

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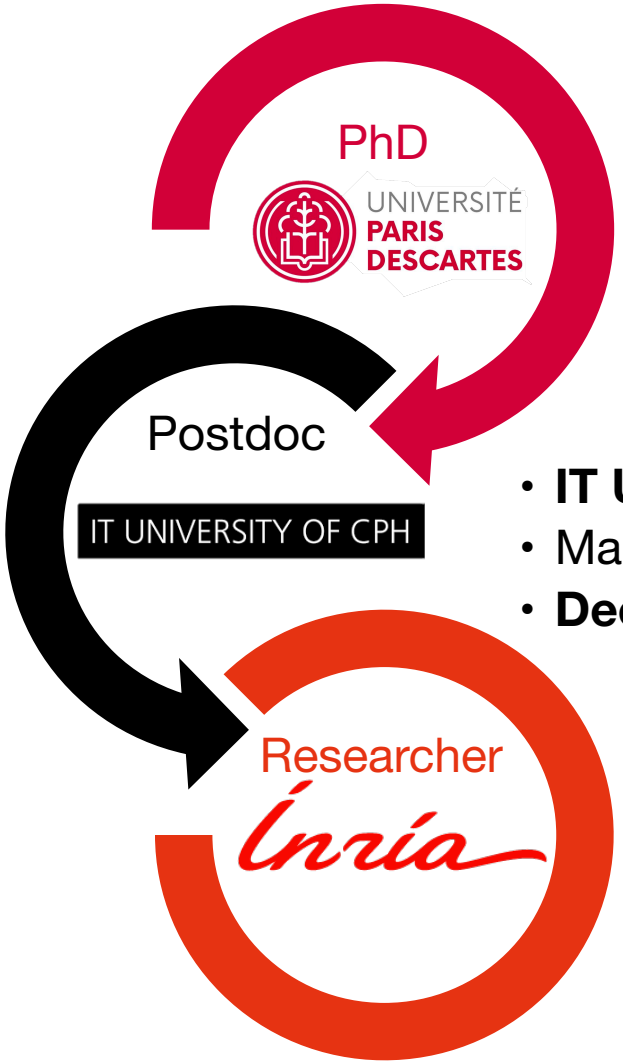
The menu for today

- **This apéritif**
  - A few things about me
  - A few **cool things about deep generative models**
  - A few things about **what we'll do in this part of the course**

- **Deep learning as a tool to build powerful generative models**
  - But actually, what is deep learning again?
  - And what are generative models?
  - Two simple examples: **regression** and **classification** (with some **coding**!)

A few things about me



- MAP5 lab, **Université Paris Descartes** (2014-2017)
- Advisors: Charles Bouveyron and Pierre Latouche
- Dissertation: **Model selection for sparse high-dimensional learning**

- **IT University of Copenhagen**, Denmark (2017-2019)
- Main collaborator: Jes Frellsen
- **Deep generative models**, in particular **variational autoencoders (VAEs)**

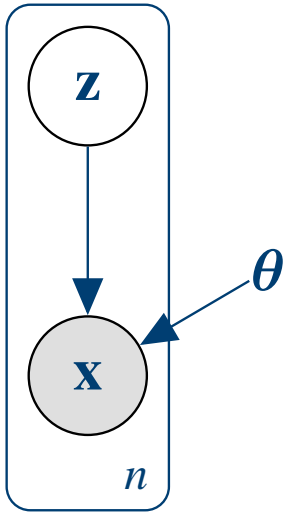
- Just started last month!
- **Deep learning**, and its connections with **statistics**

What are deep generative models (DGMs)?

- Generative models that **leverage deep learning**.
- Include **variational autoencoders** (VAEs), **generative adversarial networks** (GANs), **normalising flows**, **autoregressive models**
- **Nonlinear generalisations** of factor analysis, PCA, topic models…

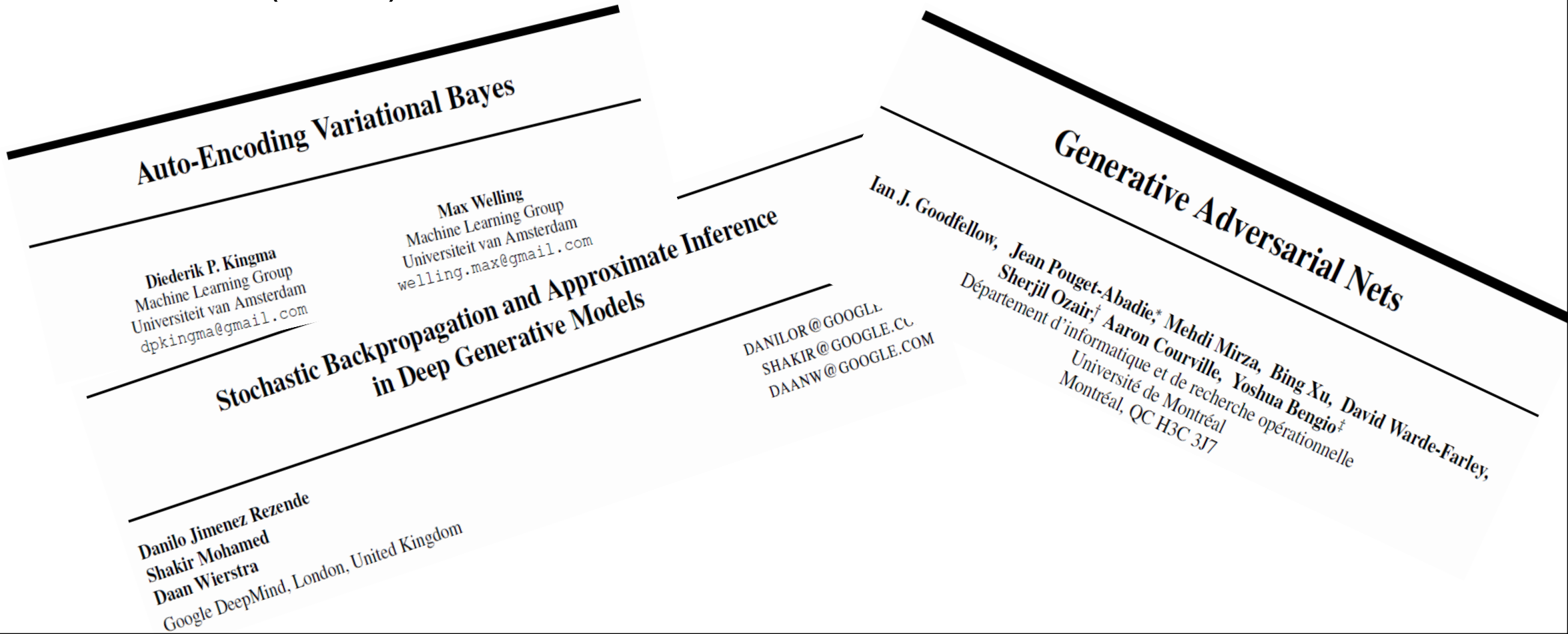
$$\begin{cases} \mathbf{z} \sim p(\mathbf{z}) \\ \mathbf{x} \sim p_{\boldsymbol{\theta}}(\mathbf{x} \mid \mathbf{z}) = \Phi(\mathbf{x} \mid f_{\boldsymbol{\theta}}(\mathbf{z})) \end{cases}$$

Deep neural network
(decoder, generator)



A brief (and **very** incomplete) history of DGM

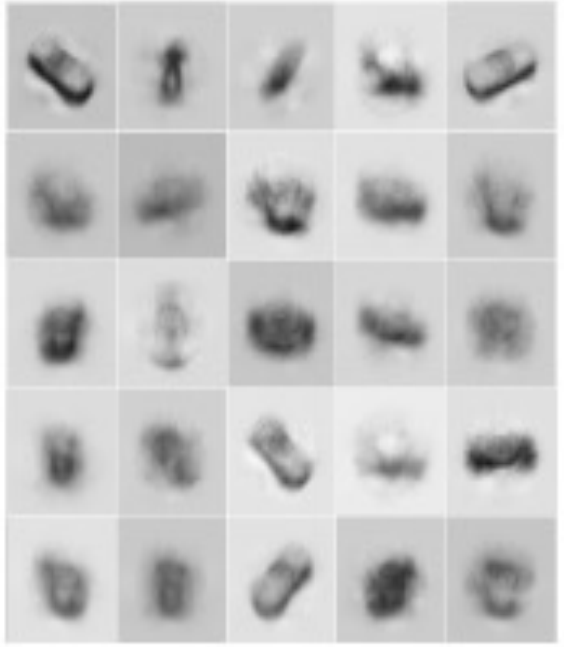
- In 2014, both **variational autoencoders** (VAEs) and **generative adversarial networks** (GANs) were invented



Early results (2014)

Training images

Images generated by a VAE

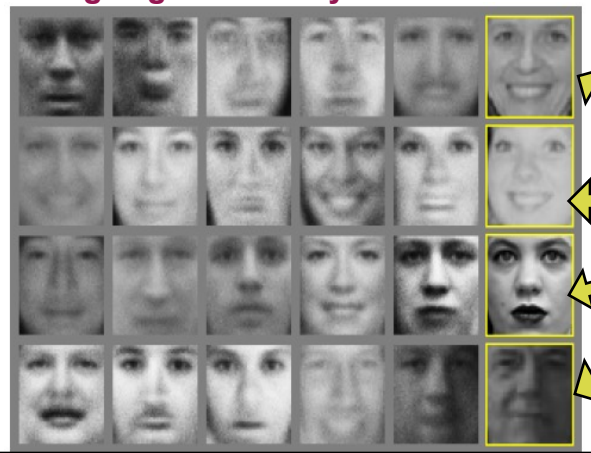


Rezende, Mohamed, and Wiestra (ICML 2014)

Images generated by a VAE

Kingma and Welling (ICLR 2014)

Images generated by a GAN



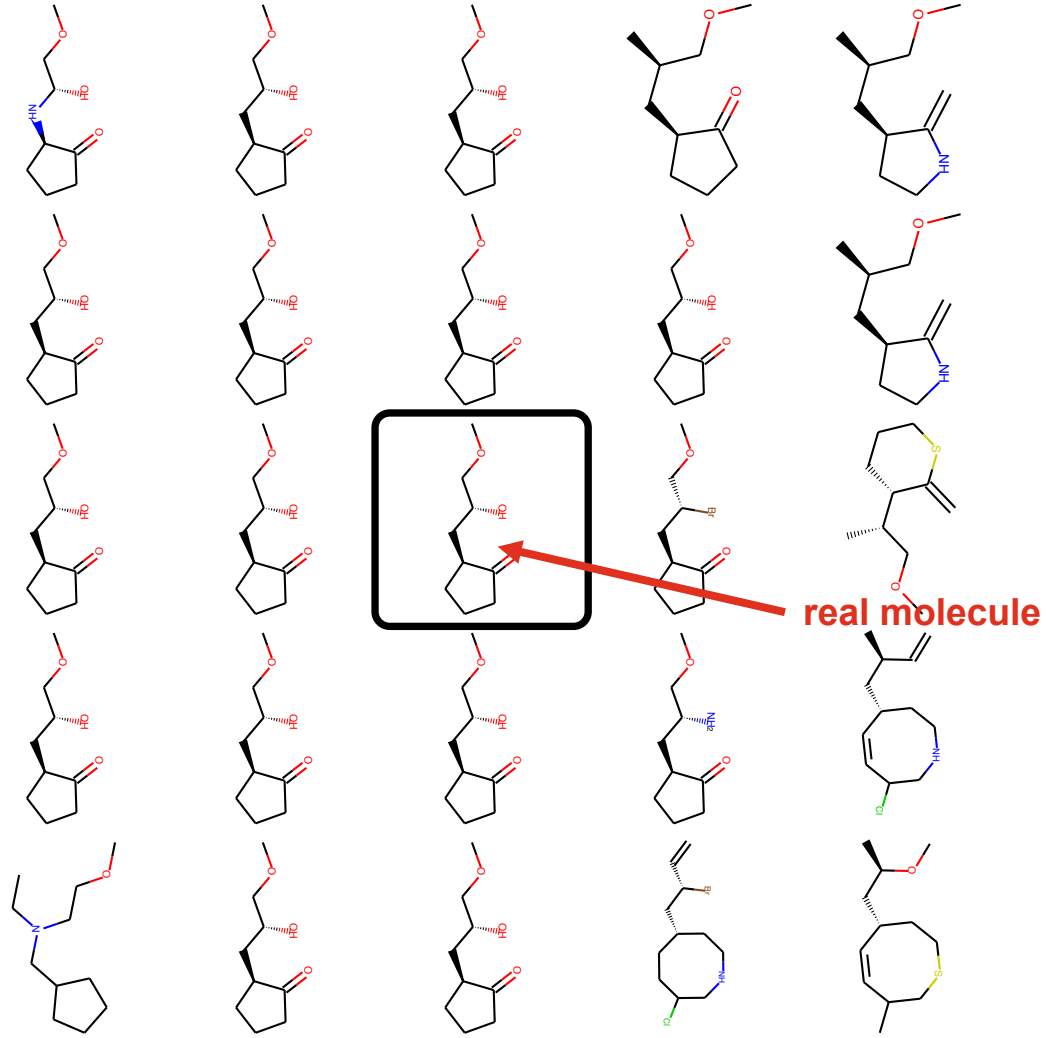
Goodfellow, Pouget-Abadie, Mirza, Xu, Warde-Farley, Ozairy, Courville, and Bengio (NeurIPS 2014)

Recent successes: generating « fake » data

Images generated by a GAN

Brock, Donahue, and Simonyan (ICLR 2019)

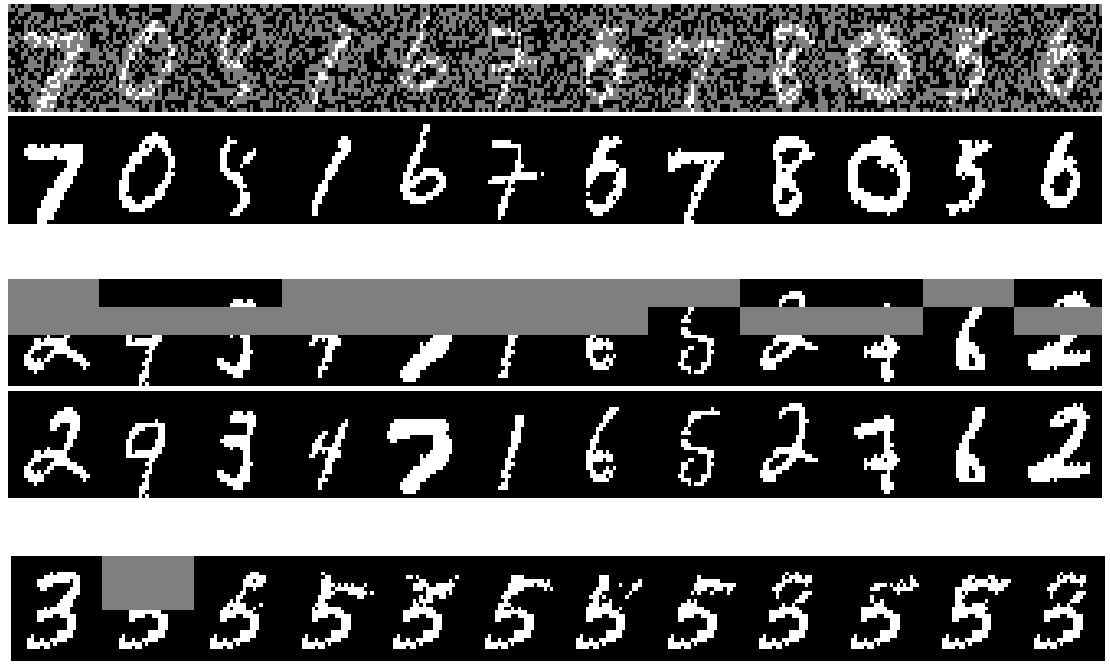
Designing new molecules with a VAE



Kusner, Paige, and Hernández-Lobato (ICML 2017)

Recent successes: enhancing data quality

Missing data imputation with a VAE



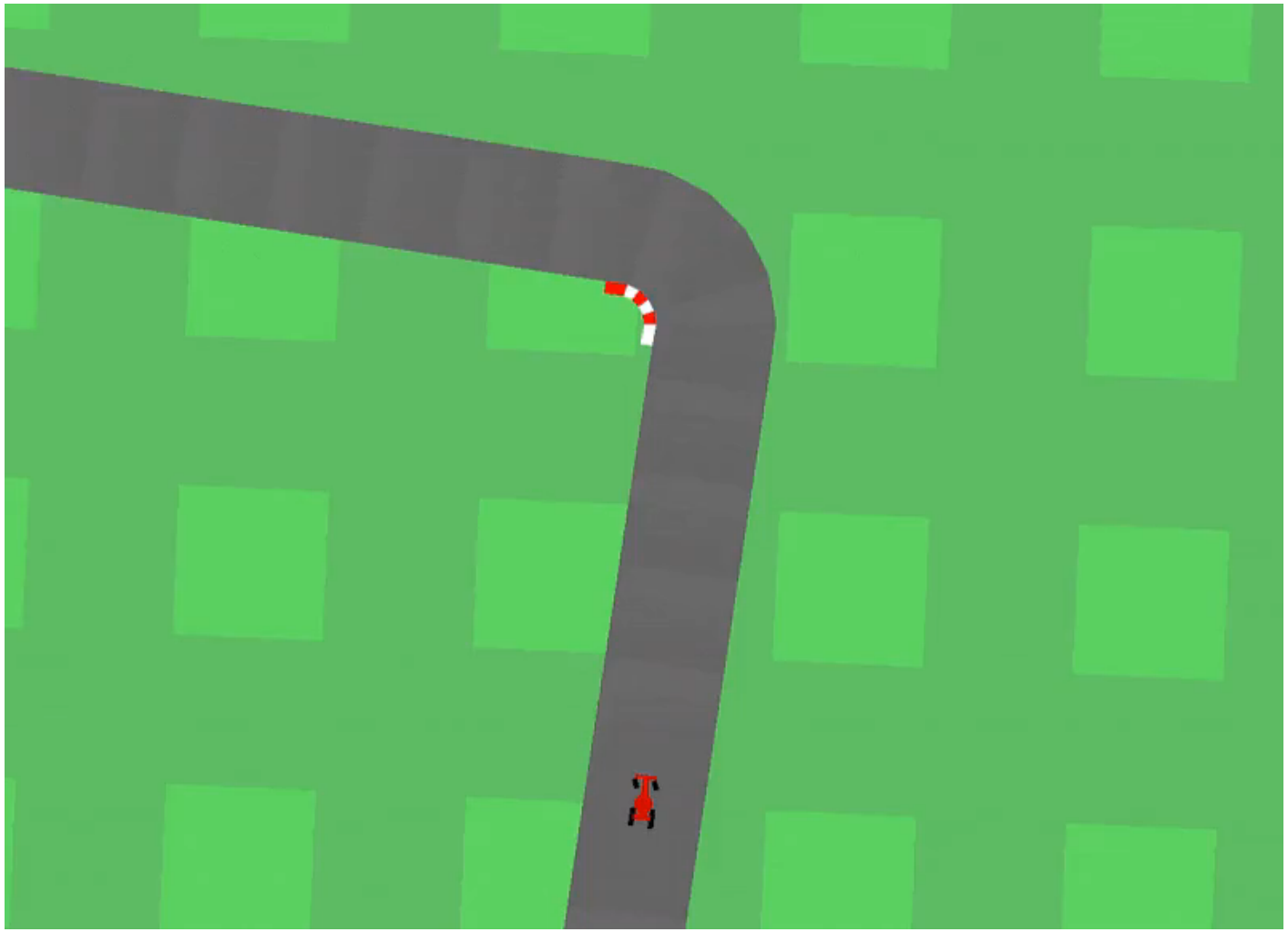
Mattei and Frellsen (ICML 2019)

Colorising with a GAN

Jason Antic, DeOldify project (github.com/jantic/DeOldify)

Recent successes: reinforcement learning

Learning to drive a car with a VAE



Ha and Schmidhuber (NeurIPS 2018)

Recent successes: reinforcement learning

Learning to dodge fireballs with a VAE

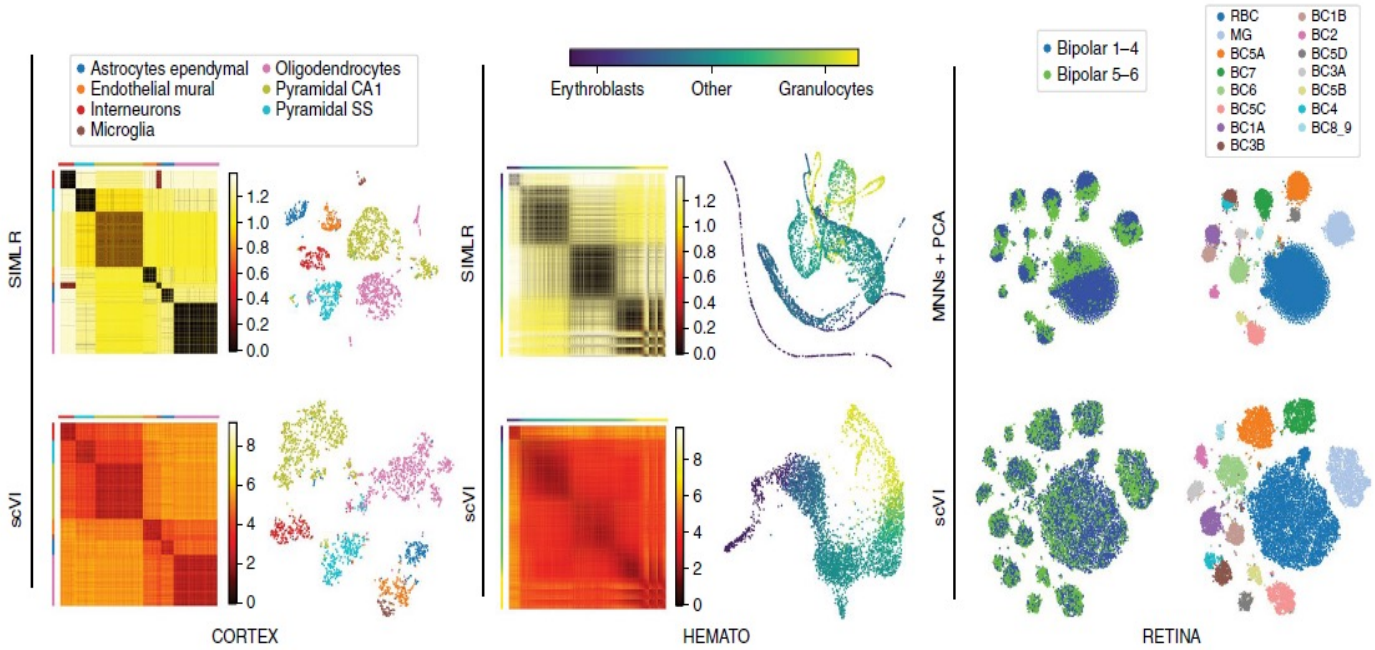
Ha and Schmidhuber (NeurIPS 2018)

Recent successes: applications in a lot of different domains

nature methods

Deep generative modeling for single-cell transcriptomics

Romain Lopez[1], Jeffrey Regier[1], Michael B. Cole[2], Michael I. Jordan[1,3] and Nir Yosef[1,4,5*]



Bowman, Vilnis, Vinyals, Dai, Jozefowicz, and Bengio (CoNLL 2016)

" i want to talk to you . "
"i want to be with you . "
"i do n't want to be with you . "
i do n't want to be with you .
she did n't want to be with him .

he was silent for a long moment .
he was silent for a moment .
it was quiet for a moment .
it was dark and cold .
there was a pause .
it was my turn .

Interpolating between « true » sentences using a VAE

What we'll do in the coming weeks

- Review **neural nets** and **probabilistic models**
- **Review (non-deep) latent variable models**
- Learn to marry the two worlds to design **deep latent variable models (DLVMs)**, that encompass both GANs and VAEs
- Learn how to do **inference in these DLVMs**, both VAE-style and GAN-style
- We'll **focus on VAEs**, because I think they are simpler to work with than GANs, but we'll also talk about deep generative models **beyond VAEs/GANs**, like **flows** or **autoregressive models**
- We will **code VAEs** (and VAE-like models like IWAEs) and play a lot with them
- The slides and Jupyter notebooks will be on my website **pamattei.github.io**

Useful references for the course (freely available online)

- **Pattern Recognition and Machine Learning**, Christopher Bishop, Springer (2006)
  - It may be from 2006 but it still is one of the best books on machine learning! For this course, mostly the chapters on probability distributions and generative models (Chapters 1, 2, 8, 12).

- **Deep Learning**, Ian Goodfellow, Aaron Courville, and Yoshua Bengio, MIT Press (2016)
  - For everything deep learning! including deep generative models (all of Part III of the book, notably Chapters 16-20).

- **A Tutorial on Deep Latent Variable Models of Natural Language**, Yoon Kim, Sam Wiseman, Alexander Rush, (EMNLP 2018)
  - A tutorial from a natural language processing conference on deep latent variable models (the models linked to VAEs). It's very well written and useful even if you don't really care about natural language processing applications. There's also a video!