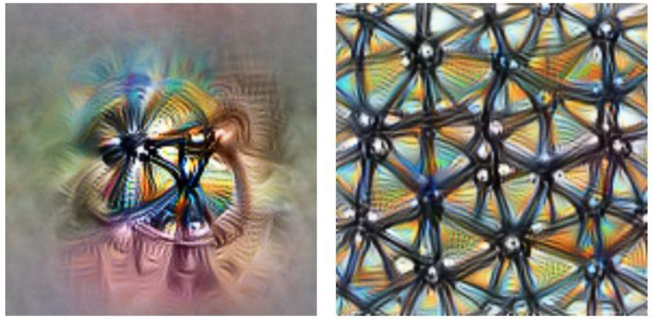
Seminar/project topics

proposed topics are grouped in five areas:

1. understanding deep neural networks
2. overview on other ML techniques
3. natural language processing
4. advanced computer vision
5. machine learning in physics
6. datasets and pretrained models

Seminars: understanding deep neural networks



Feature visualization answers questions about what a network — or parts of a network — are looking for by generating examples.

1. **Techniques that allow understand more on how and why deep architectures work**

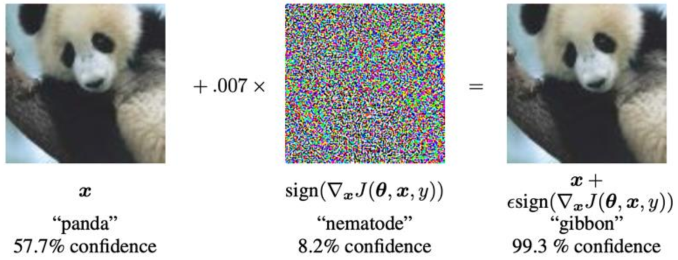
- https://distill.pub/2020/circuits/early-vision/
- https://ai.googleblog.com/2015/06/inceptionism-going-deeper-into-neural.html
- https://distill.pub/2017/feature-visualization/
- D. Erhan, Y. Bengio, A. Courville, P. Vincent. , Visualizing higher-layer features of a deep network (2009).
- http://arxiv.org/pdf/1506.02753.pdf
- https://arxiv.org/pdf/1312.6034v2.pdf
- https://github.com/tensorflow/lucid

2. **Fooling deep neural networks:** deep learning models are highly sensitive to carefully prepared adversarial attacks

How to generate adversarial examples? Can we use them to improve network stability?

- Szegedy, Christian, et al. “Intriguing properties of neural networks” *arXiv:1312.6199* (2013).
- Goodfellow, Ian J., Jonathon Shlens, and Christian Szegedy. “Explaining and harnessing adversarial examples” *arXiv:1412.6572* (2014).
- Papernot, Nicolas, et al. “The limitations of deep learning in adversarial settings.” *2016 IEEE European symposium on security and privacy (EuroS&P)*. IEEE (2016).
- Su, Jiawei, Danilo V. Vargas, and Kouichi Sakurai. “One pixel attack for fooling deep neural networks.” *IEEE Transactions on Evolutionary Computation* 23.5 828 (2019).

3. **Adversarial Attacks on LLMs:** https://lilianweng.github.io/posts/2023-10-25-adv-attack-llm/


+ .007 ×
=
$\boldsymbol{x}$
“panda”
57.7% confidence
$\text{sign}(\nabla_{\boldsymbol{x}} J(\boldsymbol{\theta}, \boldsymbol{x}, y))$
“nematode”
8.2% confidence
$\boldsymbol{x} + \epsilon\text{sign}(\nabla_{\boldsymbol{x}} J(\boldsymbol{\theta}, \boldsymbol{x}, y))$
“gibbon”
99.3 % confidence

4. **Defense strategies against adversarial attacks**

Overview on various techniques for defending against adversarial examples for attacking deep neural networks.

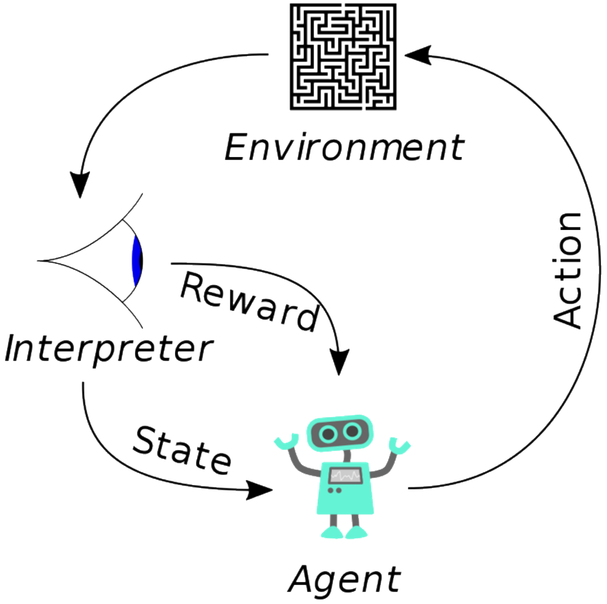
- Szegedy, Christian, et al. “Intriguing properties of neural networks” *arXiv:1312.6199* (2013).
- Xie, Cihang, et al. “Mitigating adversarial effects through randomization.” *arXiv:1711.01991* (2017).
- Das, Nilaksh, et al. “Keeping the bad guys out: Protecting and vaccinating deep learning with jpeg compression.” *arXiv:1705.02900* (2017).
- Xie, Cihang, et al. “Feature denoising for improving adversarial robustness.” *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition* (2019).
- Goodfellow, Ian J., Jonathon Shlens, and Christian Szegedy. “Explaining and harnessing adversarial examples” *arXiv:1412.6572* (2014).

Seminars: overview on other ML techniques

1. **Reinforcement Learning**

Basics and applications

- https://arxiv.org/pdf/cs/9605103.pdf
- https://mpatacchiola.github.io/blog/2016/12/09/dissecting-reinforcement-learning.html
- https://deepsense.ai/what-is-reinforcement-learning-the-complete-guide/



2. **Hidden Markov model**

Definition and example applications

- https://jonathan-hui.medium.com/machine-learning-hidden-markov-model-hmm-31660d217a61
- http://www.cs.sjsu.edu/~stamp/RUA/HMM.pdf

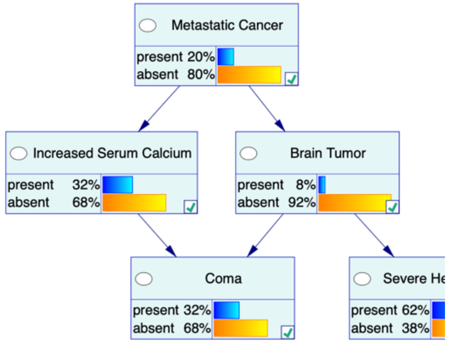
3. **Recommender systems**

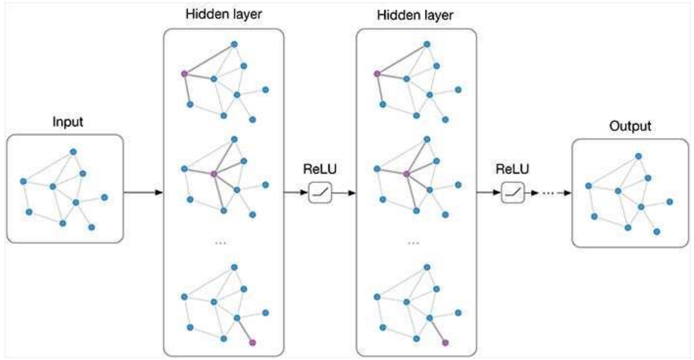
Idea, applications and the Netflix Price

- https://arxiv.org/pdf/1203.4487.pdf
- https://towardsdatascience.com/introduction-to-recommender-systems-6c66cf15ada

4. **Bayesian networks**

- https://repo.bayesfusion.com/bayesbox.html
- http://www.eng.tau.ac.il/~bengal/BN.pdf
- http://www.niedermayer.ca/node/35





Seminars: natural language processing, NLP

1. **Optical character recognition (OCR)**
- problem definition
- classical or neural network approach: an overview
- presenting one particular engine, e.g. state-of-the-art *Tesseract* (what deep learning model is used inside?)
- https://tesseract-ocr.github.io/tessdoc/
- https://huggingface.co/spaces?category=ocr

2. **Automatic speech recognition (ASR)**
- problem definition
- possible applications
- databases (e.g. *Librispeech*)
- an overview on single specific algorithm, e.g. *ContextNet* or *Deep Speech*
- https://arxiv.org/pdf/2005.03191.pdf
- https://arxiv.org/pdf/1512.02595.pdf

3. **Machine Translation**
- problem definition, example methods
- https://huggingface.co/spaces?category=language-translation

4. **Question Answering**
- problem definition, example methods
- https://huggingface.co/spaces?category=question-answering

Seminars: computer vision

1. **Point Feature Matching**

- problem definition
- classical and deep learning approaches
- *SuperGlue* algorithm: https://arxiv.org/abs/1911.11763

2. **Pose estimation**

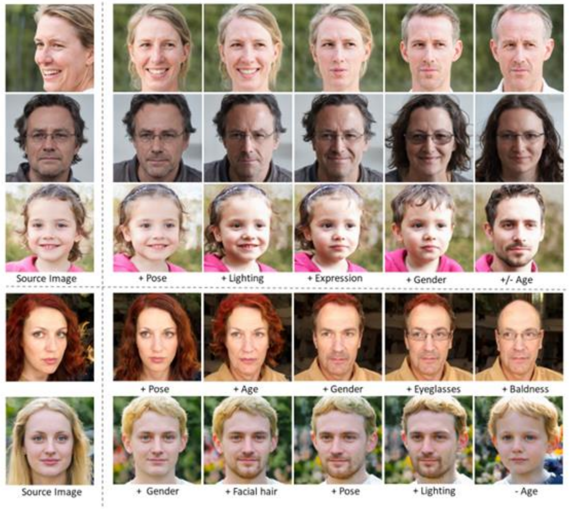
- problem definition and deep-learning solution, e.g.:
- https://arxiv.org/pdf/1803.08225.pdf

3. **Super-Resolution**

- idea, applications, algorithms
- https://arxiv.org/abs/1809.00219

4. **Editing GANs latent space**

- https://medium.com/codex/how-to-edit-images-with-gans-controlling-the-latent-space-of-gans-afde630e53d1
- https://www.unite.ai/editing-a-gans-latent-space-with-blobs



Seminars: machine learning in physics

1. **Physics-informed neural networks**

- https://benmoseley.blog/my-research/so-what-is-a-physics-informed-neural-network
- https://maziarraissi.github.io/PINNs
- seminal paper: https://www.sciencedirect.com/science/article/abs/pii/S0021999118307125

2. **Group-equivariant neural networks**

- original paper: https://proceedings.mlr.press/v48/cohenc16.pdf
- https://uvagedl.github.io

3. **Neural network quantum states**

- https://www.science.org/doi/10.1126/science.aag2302

4. **Classical shadows**

- https://www.science.org/doi/10.1126/science.abk3333
- https://pennylane.ai/qml/demos/tutorial_classical_shadows

5. **Neural tangent kernels**

- https://arxiv.org/abs/1806.07572
- https://lilianweng.github.io/posts/2022-09-08-ntk/

Seminars: machine learning in physics (cont.)

6. **SchNet**
7. **…**
8. **Need more advanced topics?** https://lilianweng.github.io/

- inspiring blogs with in-depth analysis of various aspects of deep learning

Projects: interesting datasets

1. https://huggingface.co/

- popular web service with interesting datatsets and ready-to-use models (SOTA in many cases)

2. https://www.kaggle.com/

- machine-learning competitions supported by plenty of datasets,
- e.g. butterfly classification https://www.kaggle.com/datasets/phucthaiv02/butterfly-image-classification

3. https://paperswithcode.com/

- ML scientific papers supported by models + datasets

4. Classical datasets, https://en.wikipedia.org/wiki/List_of_datasets_for_machine-learning_research

- MNIST, Fashion-MNIST
- Iris
- CIPHAR
- ImageNet
- other somewhat older: https://github.com/jbrownlee/Datasets

5. **Need more advanced topics?** https://lilianweng.github.io/

- inspiring blogs with in-depth analysis of various aspects of deep learning