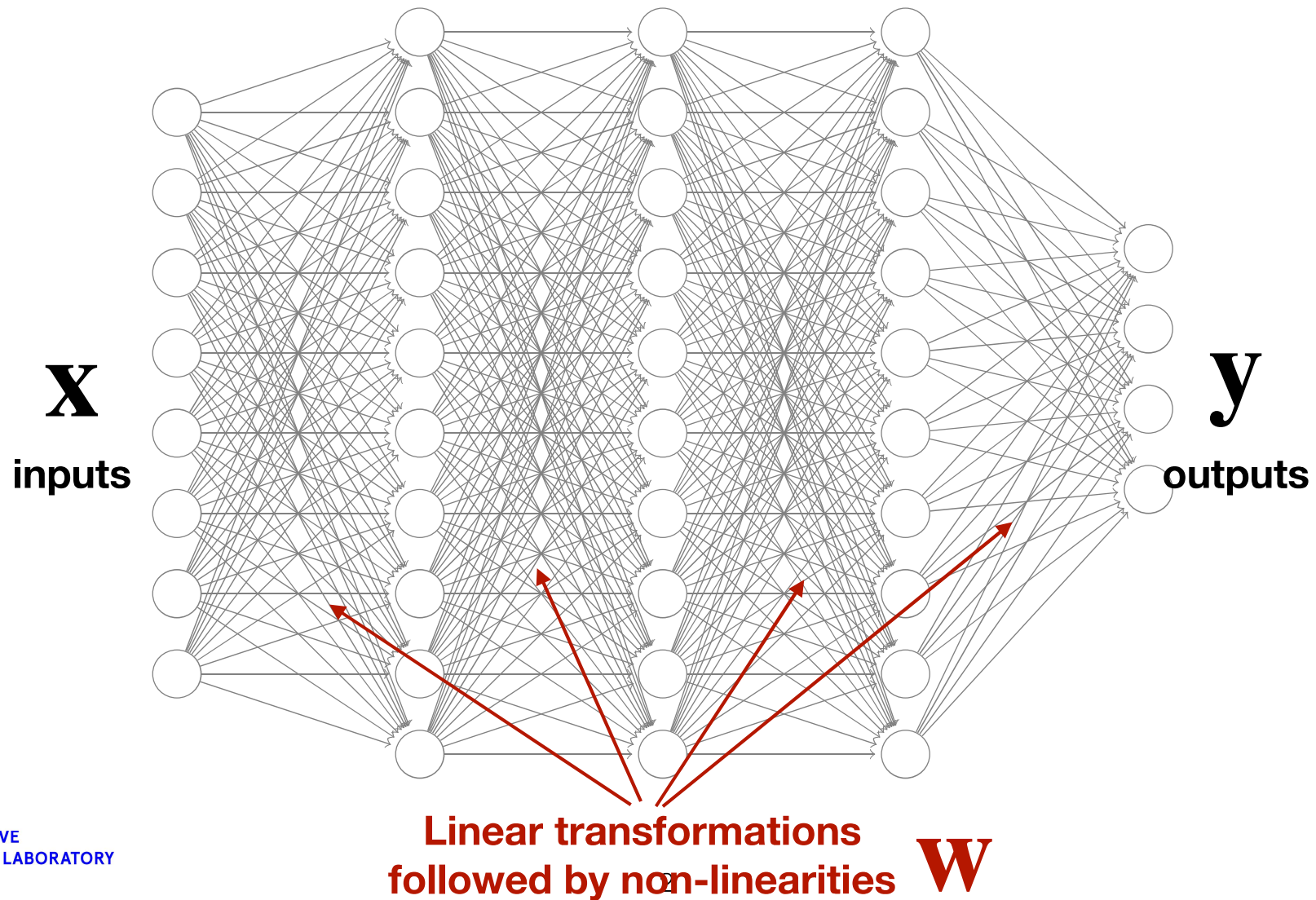


Lecture 24: Deep neural networks

Professor Ilias Bilonis

Overview of deep neural networks

Deep neural networks define functions



What can you do with deep neural networks?

- You can use them as building blocks in pretty much any machine learning task:
 - Regression
 - Classification
 - Clustering
 - Dimensionality reduction
 - Density estimation
 - Filtering
 - ...
- If you use deep neural networks, then you do **Deep Learning**.

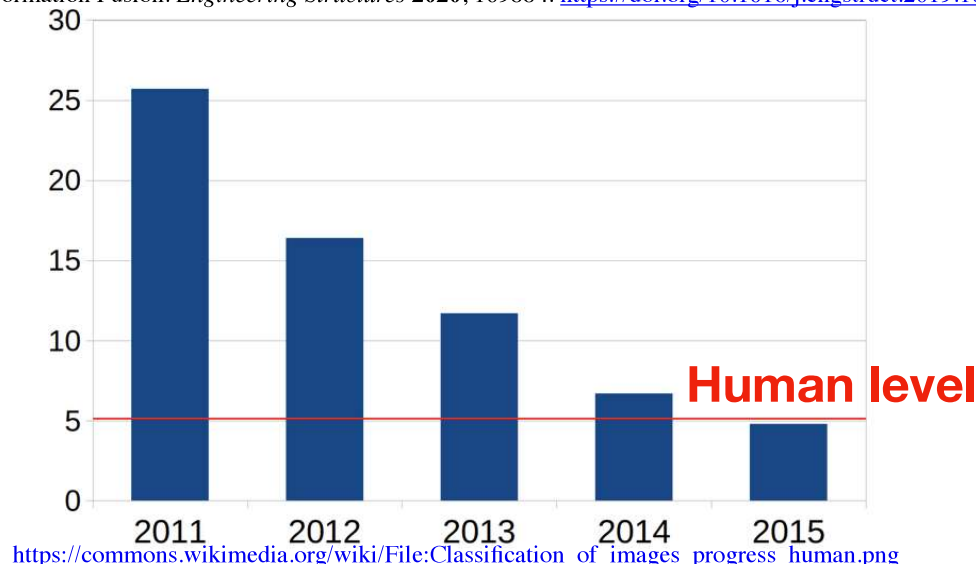
How it all started? Successes in image Classification



(a) One Story

(b) Two Stories

Lenjani, A.; Dyke, S. J.; Billionis, I.; Yeum, C. M.; Kamiya, K.; Choi, J.; Liu, X.; Chowdhury, A. G. Towards Fully Automated Post-Event Data Collection and Analysis: Pre-Event and Post-Event Information Fusion. *Engineering Structures* **2020**, 109884. <https://doi.org/10.1016/j.engstruct.2019.109884>.



Other successful applications of deep neural networks

- Natural language processing
- Speech recognition
- Reinforcement learning:
 - self-driving cars
 - playing Atari games
 - AlphaGo
- Design of engineering systems (see physics-informed ML)

Why do deep neural networks work so well?

- The universal approximation theorem (Cybenko, 1989).
- Deep nets find hierarchical representations of high-dimensional data.
- Advances in learning algorithms (back-propagation, stochastic gradient descent).
- Advances in software (tensorflow (Google), pytorch (Facebook)).
- Advances in hardware (GPUs (NVIDIA)).

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Why you should be careful with deep learning in engineering applications?

- Many approaches are black boxes with:
 - No theoretical guarantees on convergence/performance;
 - No explanation as to why they predict whatever they predict
-> ethics of AI, trust in human-machine interaction, etc.
- Making errors if data are perturbed by a bit (need to build symmetries in deep nets).
- Adversarial attacks.
- Too much dependence on humans for labeling.