Generative AI: Transformer Models

##$ Hugging Face NLP `pipeline()` abstraction

COMP 741/841 Week 6 - Spring 2024

Agenda

- Writing to learn (RNs)
  - References and citations
- Lab 5: Transformers

Reference writing style: ACM style

- Name. Year. Article title. Publication/source name. Optional: pages, URL.
  If journal/magazine: volume, number, exact date.
- Examples:
  - Henry A. Kautz, Bart Selman, and Michael Coen. 1994. Bottom-up design of software agents. Communications of the ACM 37, 7 (July 1994), 143–146. https://doi.org/10.1145/176789.
  - Adam Sadilekand Henry Kautz. 2012. Location-based reasoning about complex multi-agent behavior. Journal of Artificial Intelligence Research 43, 1 (January 2012), 87–133.

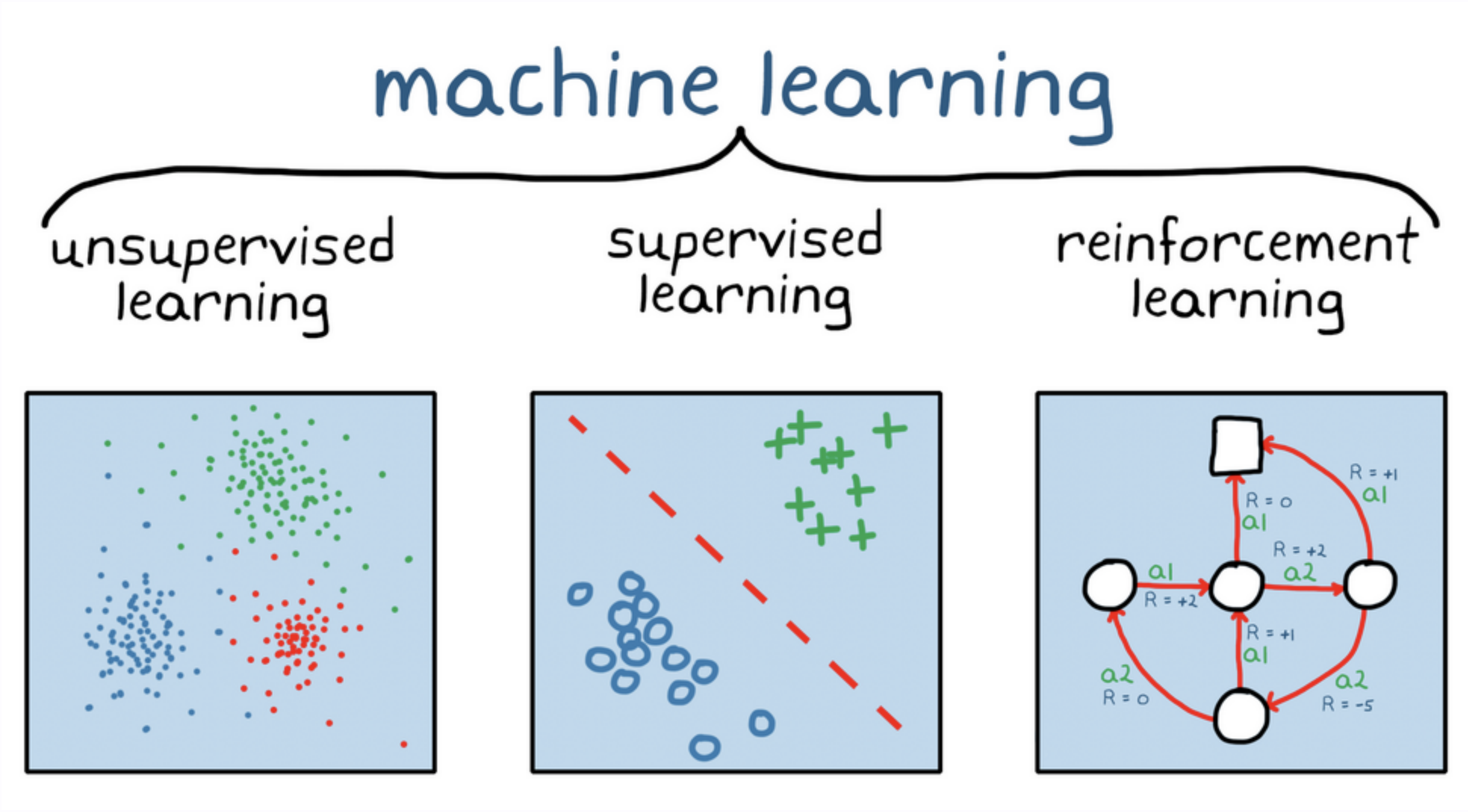
Reference citation style: (Last name(s), Year)

- Examples:
  - (Kautz et al., 1994)
  - (Sadilekand Kautz, 2012)

Transformer Models

- Are **language models**: trained on large amounts of text in a ***self-supervised*** way
- Solve **natural language processing (NLP)** tasks

Machine Learning Types



Source: MathWorks. 2024. What Is Reinforcement Learning? https://www.mathworks.com/discovery/reinforcement-learning.html.

Unsupervised Learning

- Draw inferences from the **structures** in the dataset
  - No comparision needed between **predictions** and **labels**
  - No use of any **targets** during training
  - No human intervention --> more time and cost-effective
- Methods
  - Cluster analysis
    - Discover patterns (features) in the dataset
    - Establish classes based on grouping the data
  - Feature ranking

Self-supervised Learning

- Type of **unsupervised learning**
- Statistical understanding of the unstructured data
- Learn representations using the data itself to generate targets
- Labels are
  - Automatically generated from the input data
  - Inferred from unlabeled data
- Example: generate targets by using the next word in the sentence
- Application domains: computer vision, NLP

Pretraining

To learn **meaningful representations of data**

- On huge amounts of data
- Initial weights are randomly chosen
- Predict parts of the input data from observed parts
- Takes significant time and computing resoruces

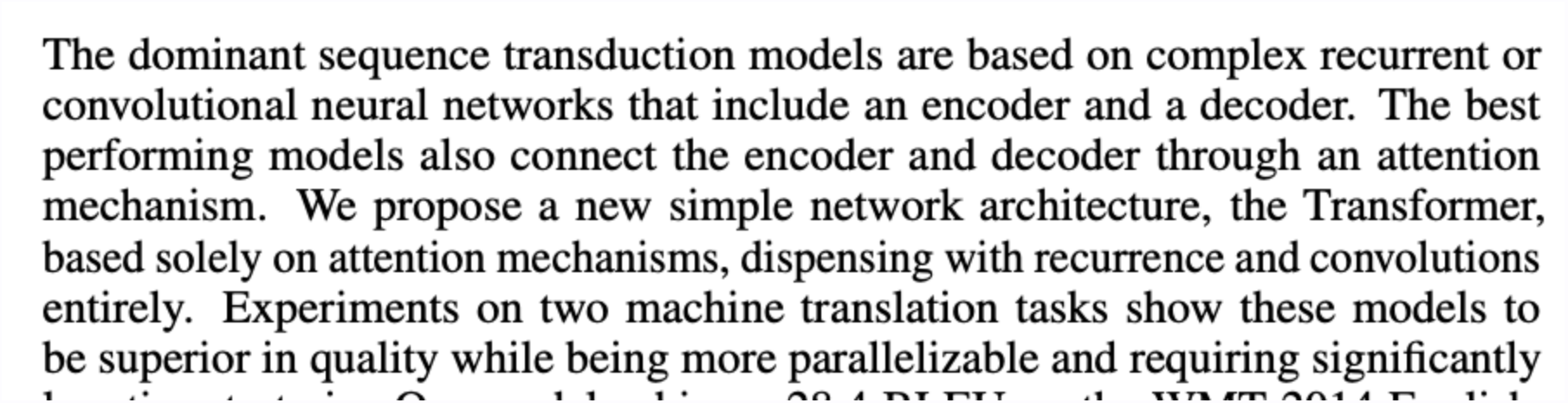
Transformer Models

- Enable **transfer learning**
  - Fine-tuning in a supervised way
  - For specific practical tasks
  - On specific, labeled dataset
- Fine-tuning
  - Lss time, less data, less environmental cost
- Task examples
  - predict next word based on previous words
  - predict missing word from a sentence

Source: Hugging Face. 2023. Transformers Models: What can they do? https://huggingface.co/learn/nlp-course/chapter1/

Origin of the Transformer Model

Ashish Vaswani, Noam Shazeer, Niki Parmar, Jakob Uszkoreit, Llion Jones,Aidan N. Gomez, Lukasz Kaiser, Illia Polosukhin. 2017. Attention is all you need. Proceedings of the 31st Conf. on Neural Information Processing Systems.



The dominant sequence transduction models are based on complex recurrent or convolutional neural networks that include an encoder and a decoder. The best performing models also connect the encoder and decoder through an attention mechanism. We propose a new simple network architecture, the Transformer, based solely on attention mechanisms, dispensing with recurrence and convolutions entirely. Experiments on two machine translation tasks show these models to be superior in quality while being more parallelizable and requiring significantly

Origin of the Transformer Model

less time to train. Our model achieves 28.4 BLEU on the WMT 2014 English-to-German translation task, improving over the existing best results, including ensembles, by over 2 BLEU. On the WMT 2014 English-to-French translation task, our model establishes a new single-model state-of-the-art BLEU score of 41.0 after training for 3.5 days on eight GPUs, a small fraction of the training costs of the best models from the literature.

Transformer Model Architecture

Task-based architectures

- Encoder-only architecture
  - Example task: sentence classification
- Decoder-only architecture
  - Example task: text generation
- Sequence-to-sequence architecture
  - Example task: text generation based on translation or summarization

Encoder Models

- Best for *analyzing* text
  - What are the main topics?
  - What is the overall sentiment?
- Trained by studying *sequences* of words
  - Has access to context to *left and right* of current word
  - Can 'see' the whole sentence
  - Sentences create context for the model
- The more times is trained on a given sequence
  - the more likely it is to predict that sequence in the future

Encoder Models

- Best for
  - Sentence (zero-shot) classification
  - Sentiment analysis
  - Mask-filling (fill-in-the-blank)
- Example: BERT

Source: Hugging Face. 2023. Encoder Models
https://huggingface.co/learn/nlp-course/chapter1/

Decoder Models

- Best for generating text
  - Example: chatbots, GPT-x
  - Only have access to context to the *left or right* the current word
  - Not aware of full sentence
- Similar to encoder models: decoder models study sequences of words
- Unlike encoder models: decoder models don’t “see” the entire sentence
  - Trained iteratively word by word using context from only one direction

Source: Hugging Face. 2023. Decoder Models
https://huggingface.co/learn/nlp-course/chapter1/

Sequence-to-sequence Models

- Best for *analyzing input and generating output*
  - Translation
  - Summarization
- Also known as encoder-decoder models
- Encoder analyzes input and passes to decoder
- Decoder is given the starting context
- Example: translation models
  - Decoder probabilistically predicts next word
  - Based on the weights for words, sentences, phrases that are passed to it by the encoder

Source: Hugging Face. 2023. Sequence-to-sequence Modelshttps://huggingface.co/learn/nlp-course/chapter1/

Shares pretrained models and datasets

- Building a language model on pretrained weights reduces the carbon footprint
- `transformers` library function call
  - `pipeline(<task>, model="...")`
- Select a pretrained model
- Fine-tune for a particular NLP task

Sentiment Analysis

- Download and cache the model to create the classifier object
- Preprocess input text so the model understands it
- Pass the input text to the model
- Model computes the predictions
- Postprocess the predictions so a human understands them.

Lab5: Transformers

- Experiments with transformer models using Hugging Face `transformers` library
- Clone **lab5** to your SageMaker Studio Lab (SMSL) CPU instance
- Follow instructions in `README.md`
- Run through the cells, answer questions, and experiment with different input
- Solve scenarios in BUSINESS-CASES.md
- Version control your `EXPERIMENT.md` and `BUSINESS-CASES.md`
- Submit to GitHub and Canvas