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Norwegian University of Science and Technology

# TDT4310, Lab 1

# Large language models and the latest developments

Tollef Jørgensen, January 16, 2024.

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Feeding AI systems on the world's beauty, ugliness, and cruelty, but expecting it to reflect only the beauty is a fantasy.

Vinay Uday Prabhu, Abeba Birhane

# Outline

- Introduction to the labs/coursework
- Language models
- GPT and friends (or enemies)
- Latest developments
- Retrieval-augmented generation
- The future and risks

# About ~~me~~ you!

- Extremely smart
- Extremely motivated
- Extremely hyped to sign up for the reference group
  - *Make the course better for everyone involved! pls*

- Email gamback@ntnu.no / tollef.jorgensen@ntnu.no :-)

# Before we continue

- A few have mentioned that there was a bit of confusion regarding where to find information - as we didn't refer to any specific sources for the questions
- The main reason for this:
  - There's no real "perfect" source
  - Getting you to look up and understand the concepts for yourself was the goal, as one source (typically a blog or research paper) will not be enough on its own

# Introduction to the assignments

- **5 total - you need to pass all of them!**
- The first one, on LLMs, is more of a questionaire
  - Perhaps overwhelming to some, but this type of introduction was requested last year!
- **2 weeks per assignment**
  - Published on mondays. The next one will be available on the deadline date.
- All should be finished before easter, so the last week is left for preparations for the graded project.

# Introduction to the assignments

- Information about the course and assignments:
  - **Please mainly use the blackboard forum**
    - Can post anonymously as well
- Sensitive information/other questions:
  - Emails (**please add [TDT4310] in the subject**)
    - If related to an assignment (sick leave, etc.)
      - Me
    - Else:
      - Björn/me + CC TA's

# Language models

- ...Many definitions, but let's go with:
  - *A model that predicts the likelihood of a sequence of tokens (words) in a given context (sentence)*
  - We consider this to be a *probabilistic model*

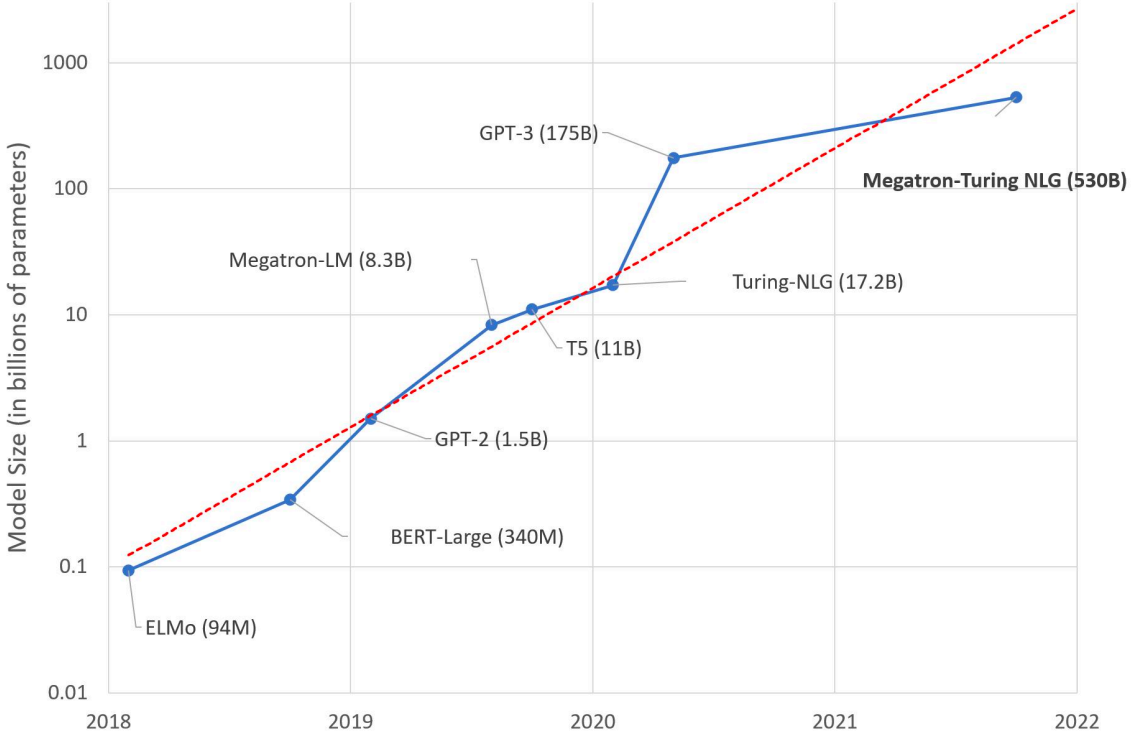
# Language models

- Early approaches:
  - Hidden Markov Models (transition probabilities for a word)
  - N-gram language models
    - "some words in a sentence"
      - (some, words), (words, in), (in, a), (a, sentence)
  - Context-free grammar: rules to generate valid strings
    - https://www.nltk.org/howto/generate.html

# Language models

- Modern:
  - Machine learning/statistical models
  - RNNs and LSTMs, Hierarchical networks, ...
  - Embeddings!
- Since 2018:
  - The transformer architecture and related models

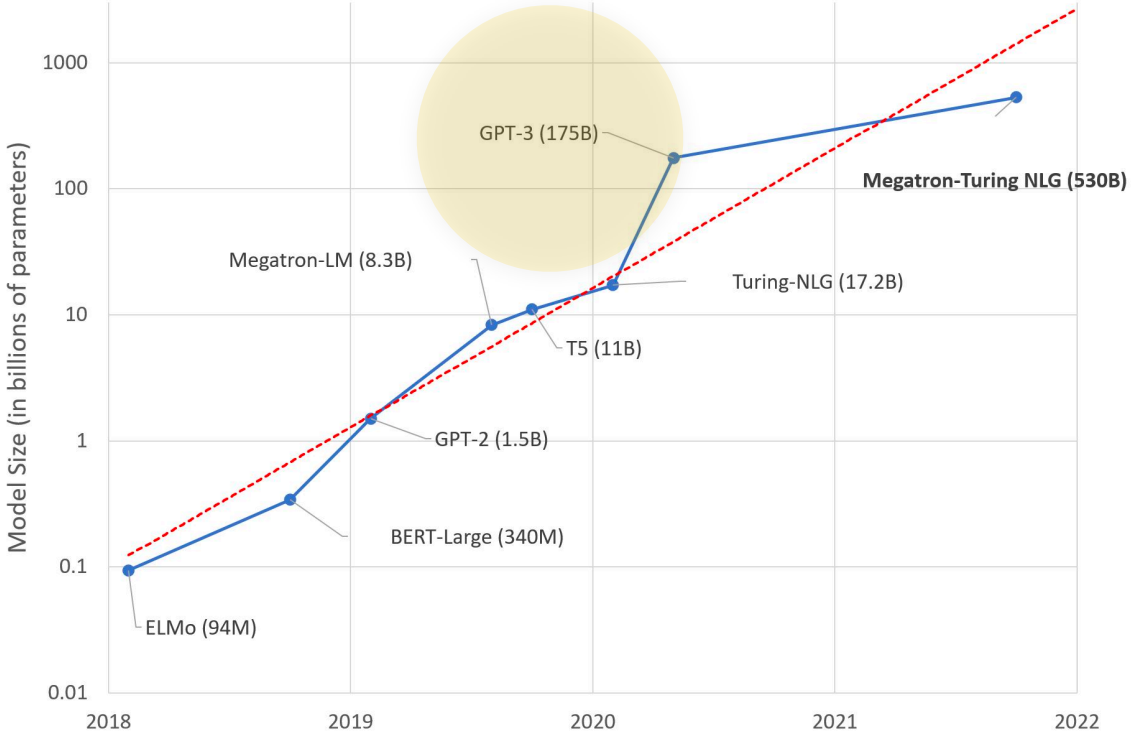
# Language models




https://huggingface.co/blog/large-language-models

# Language models

Similar to the base model of ChatGPT




https://huggingface.co/blog/large-language-models

# GPT and friends (or enemies)

- GPT, or *generative pre-trained transformer*, is nothing *new*, although the public mostly became aware of the term after the release of ChatGPT in 2022
- It was released in its first version back in 2018 by OpenAI
  - Limited data sources and size, although it was definitely big at the time!
  - Based on GPT3, in an updated "GPT 3.5" variant
- Model sizes were scaled up before the release of ChatGPT. This was due to the "scaling laws" we observed for transformer based models
  - More data + more parameters = better models...
  - This, however, is not so simple anymore!

# GPT and friends (or enemies)

- DeepMind
  - Chinchilla family + Gopher, 2021 (gpt-2 with modifications)
    - from 44M to **280B** parameters
- Google
  - PaLM (2022) and PaLM-2 (2023) , 340-540B
  - Gemini (currently experimental)
- OpenAI
  - GPT series (117M, 1.5B, 175B, ???B) - Rumours say up to 1.7 trillion?!

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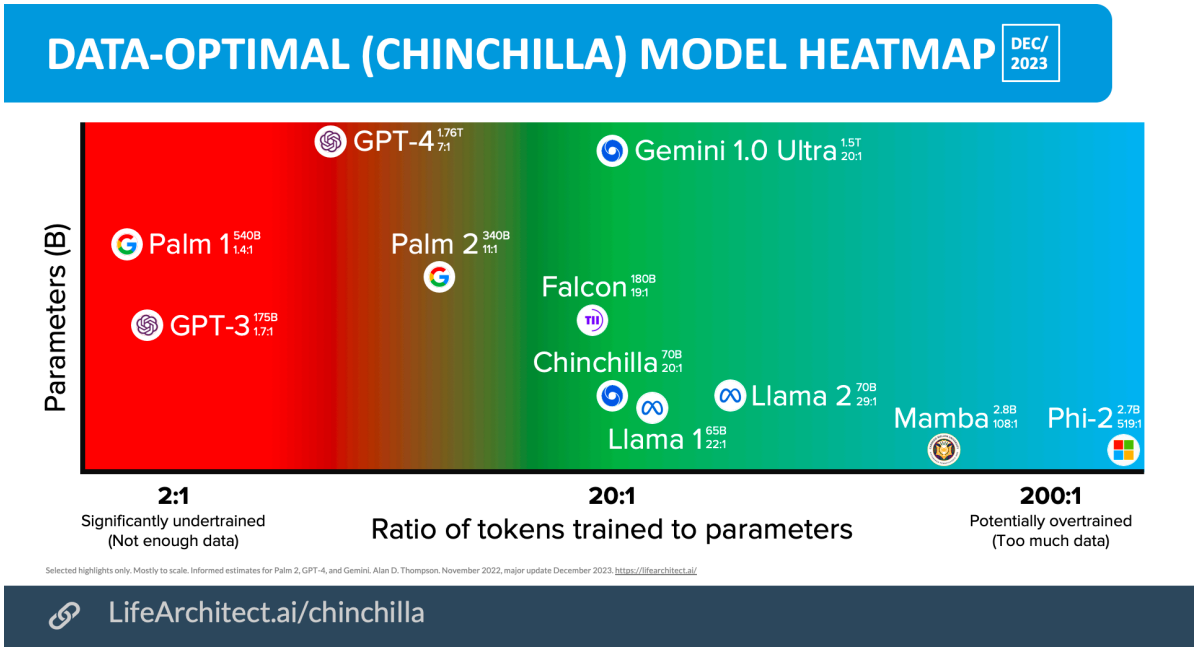
# Chinchilla optimality/scaling laws

- Claimed to find an optimal ratio:
  - Training tokens vs number of parameters



# Chinchilla optimality/scaling laws

- Claim:
  - We need to be using 11× more data during training than that used for GPT-3 and similar models.
  - Need to source, clean, and filter around **33TB** of text data for a **1T-parameter model**.

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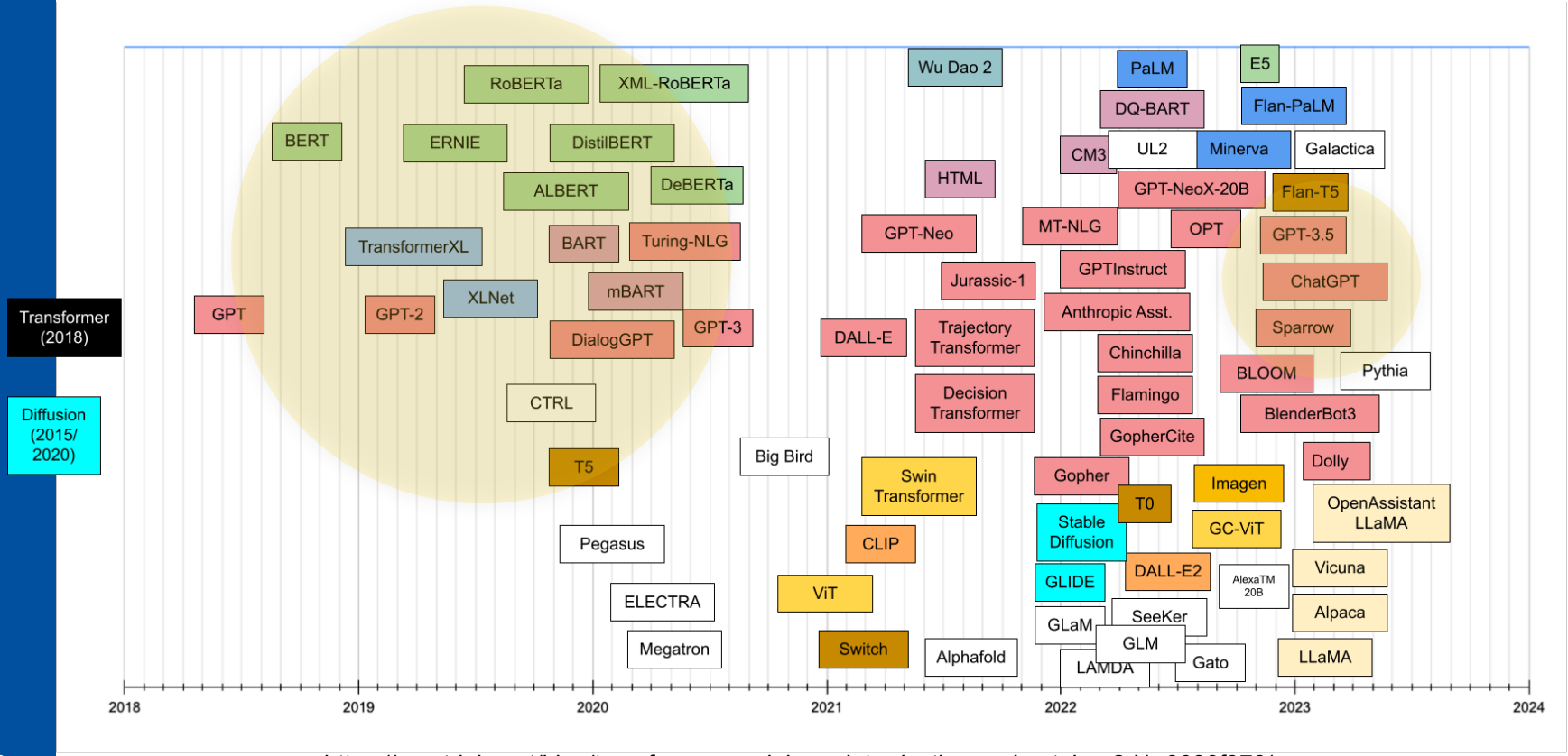
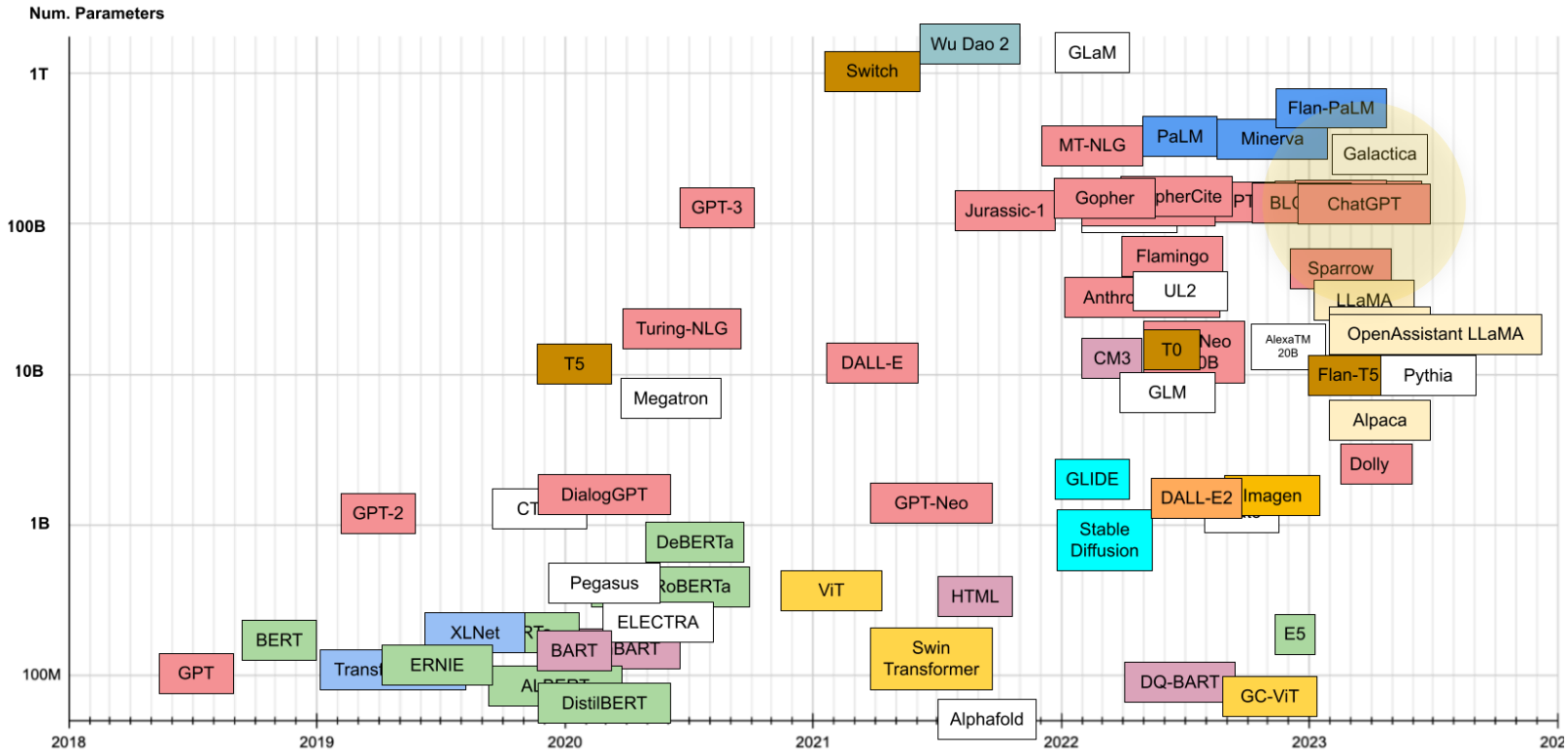
... But there's more ...

# Chronological timeline

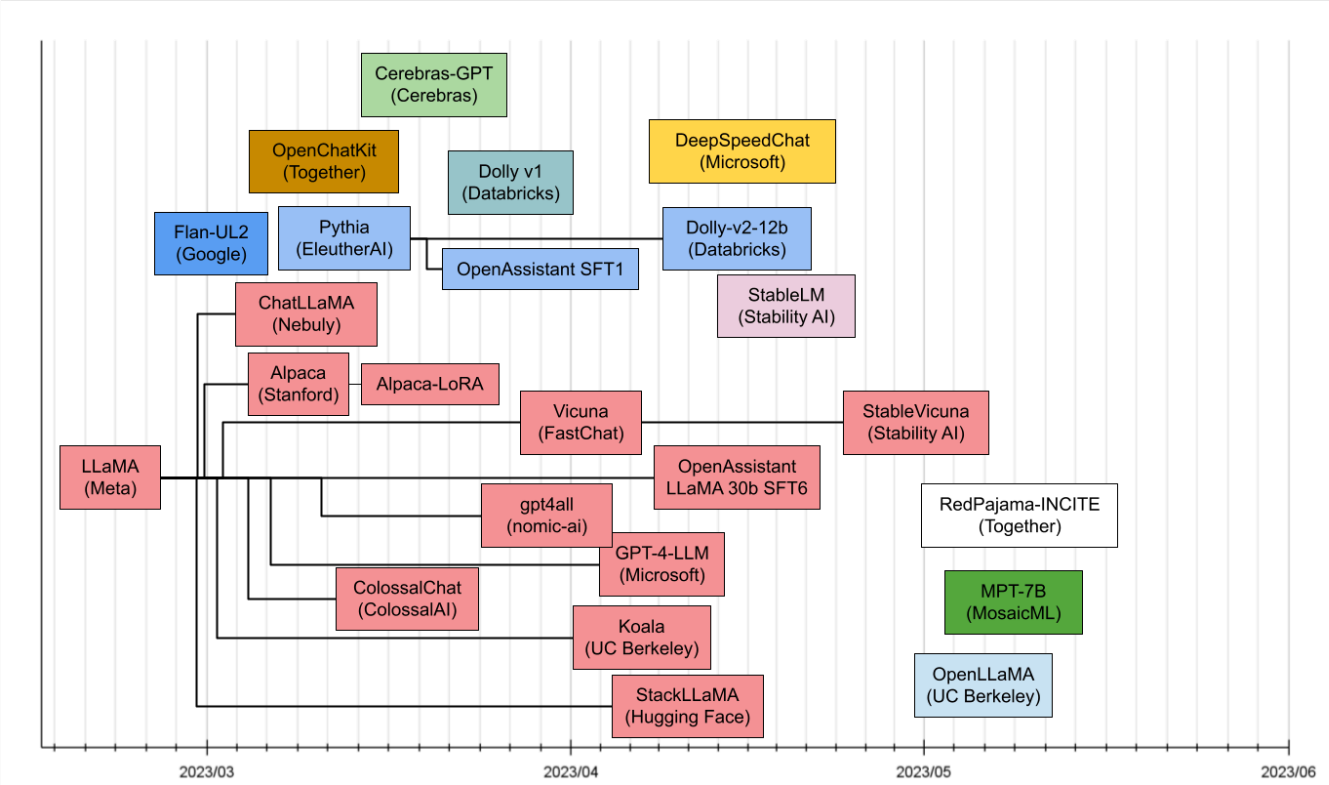



https://amatriain.net/blog/transformer-models-an-introduction-and-catalog-2d1e9039f376/

# Y-axis = N parameters



# The surge of open-sourced LLMs. Thanks, Meta 🤗



Learnable part of the system

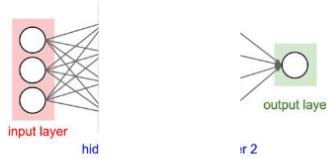
## Rule-based systems

Input → Hand-designed program → Output

## Classical machine learning

Input → Hand-designed features → Mapping from features → Output → Hand- designed loss function

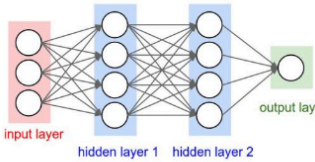
logistic regression




## Deep learning: (self-)supervised learning

Input → Learned features → Mapping from features → Output → Hand- designed loss function

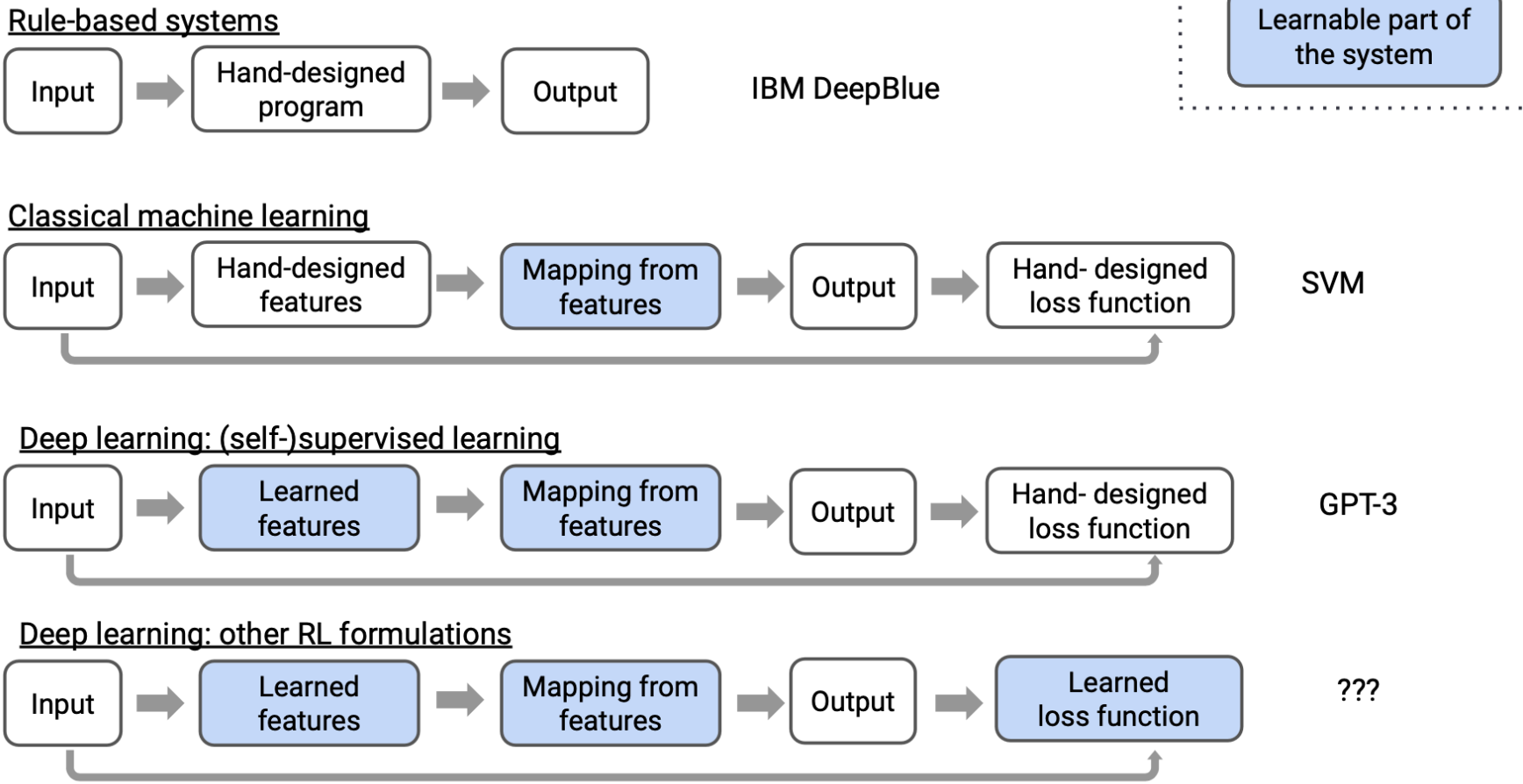
Feedforward neural net




## Deep learning: other RL formulations

Input → Learned features → Mapping from features → Output → Learned loss function

Hyung Won Chung, OpenAI



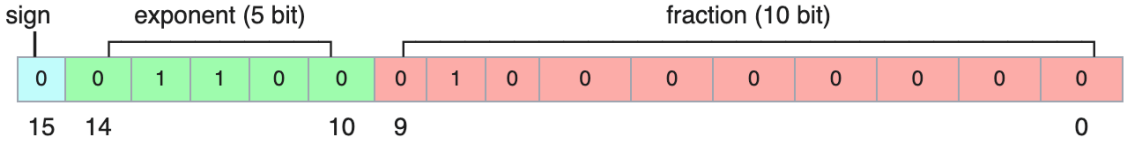

Hyung Won Chung, OpenAI

# A question

- What is the difference between a base model and what we think of when we hear "LLMs" today?
  - One of the questions to this weeks assignment

# The latest stuff

- Running models on consumer-grade hardware with post-training *quantization*
  - A 16-bit floating point requires 2 bytes. If we can reduce this, we reduce both the hardware required for inference + the space on disk.
    - A 70B model (such as LLaMA) requires 70B * 2 bytes
      - 140 GB!
  - Done by adjusting the dynamic range and precision of floating points



# Floating Point Formats

## bfloat16: Brain Floating Point Format

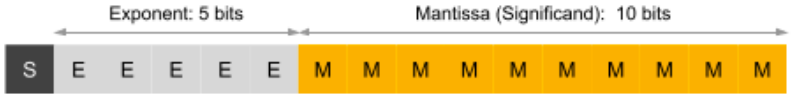
**Range: ~1e$^{-38}$ to ~3e$^{38}$**


## fp32: Single-precision IEEE Floating Point Format

**Range: ~1e$^{-38}$ to ~3e$^{38}$**


## fp16: Half-precision IEEE Floating Point Format

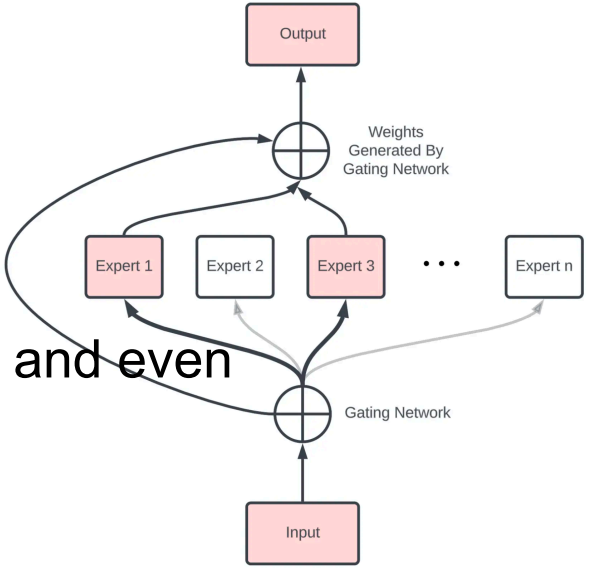
**Range: ~5.96e$^{-8}$ to 65504**




https://cloud.google.com/tpu/docs/bfloat16

# The latest stuff

- Mistral-7B is all the rage
  - A "small" model - only 7B parameters
  - Outperforms larger models like the 13B and even 30B+ models at certain benchmarks
- *Very* recently: Mixtral 8x7B
  - a *mixture-of-experts* model
  - Input is passed to a selection of expert sub-networks
    - One expert may be more suitable than another for a specific task.




MISTRAL AI_

https://mistral.ai/

# The latest stuff

- Even smaller:
  - TinyLlama 1.1B (published a Jan, 2024)
    - Everything open sourced! 🙌
- Still a way to go, but developments are rapid!
  - Open sourcing model weights lead to...
    - Instruction tuning on top of new datasets
    - Merged models
    - Different quantization methods
  - You end up with model names like...
    - OpenAssistant-Llama2-13B-Orca-8K-3319-GPTQ
      - Llama-2 fine-tuned on the orca-chat dataset, done by OpenAssistant, trained for 3319 steps, quantized with GPTQ

# The latest stuff

- Adding information to language models
  - Retrieval-augmented generation (RAG)

- Composing models as *agents*
  - Example: LangChain
    - *https://github.com/langchain-ai/langchain*

# Retrieval-augmented generation

- You've likely heard about the *knowledge cut-off*
  - E.g. in ChatGPT, they need to train or perform continued training on new data up to a certain point in time.
    - Essentially the entire web... Although this is not disclosed by OpenAI.
    - Currently cut-off to January, 2022.
- What is an obvious limitation to the way LLMs are trained?
  - Consider this: we are interacting with the existing weights of the model

# Retrieval-augmented generation

- Retrieval-augmented generation (RAG)
  - Add information into the context of the LLM
- Information can be
  - Knowledge bases (or just data from e.g. wikipedia or any other source)
  - Incorporate searches
  - ∞

# The future

- New architectures (Mamba is up-and-coming, moving away from the transformer)
- Ethical considerations
- Reliability and explainability
- Smaller models
  - Current LLMs are both expensive and energy-consuming
- Evaluation approaches

# The future - Evaluation

- Currently, most teams behind models evaluate on a selection of benchmarks
  - Monitored on LLM leaderboard:
    - https://huggingface.co/spaces/HuggingFaceH4/open_llm_leaderboard

*A woman is outside with a bucket and a dog. The dog is running around trying to avoid a bath. She...*

*A. rinses the bucket off with soap and blow dry the dog's head.*

*B. uses a hose to keep it from getting soapy.*

***C. gets the dog wet, then it runs away again.***

*D. gets into a bath tub with the dog.*

Example from *HellaSwag*

# The future - Evaluation

- More trustworthy/realistic:
  - Let users ask questions and rank answers anonymously
    - No inclusion of predefined questions
  - https://chat.lmsys.org/
  - https://huggingface.co/spaces/lmsys/chatbot-arena-leaderboard

| Rank | Model | Arena Elo | 95% CI | Votes | Organization | License |
|---|---|---|---|---|---|---|
| 1 | GPT-4-Turbo | 1249 | +14/-13 | 23069 | OpenAI | Proprietary |
| 2 | GPT-4-0314 | 1190 | +14/-14 | 16237 | OpenAI | Proprietary |
| 3 | GPT-4-0613 | 1160 | +14/-12 | 20884 | OpenAI | Proprietary |
| 4 | Mistral Medium | 1150 | +15/-13 | 6586 | Mistral | Proprietary |
| 5 | Claude-1 | 1149 | +15/-13 | 16956 | Anthropic | Proprietary |
| 6 | Claude-2.0 | 1131 | +14/-13 | 11204 | Anthropic | Proprietary |
| 7 | Mixtral-8x7b-Instruct-v0.1 | 1123 | +15/-13 | 12469 | Mistral | Apache 2.0 |
| 8 | Gemini Pro (Dev) | 1120 | +18/-18 | 1898 | Google | Proprietary |
| 9 | Claude-2.1 | 1119 | +14/-12 | 20883 | Anthropic | Proprietary |
| 10 | GPT-3.5-Turbo-0613 | 1116 | +13/-13 | 26583 | OpenAI | Proprietary |

# Risks

- Environmental and financial costs
  - Minimal improvements lead to massive costs...
- Unmanageable training data
  - And where does the data come from?
  - Is it representative? (e.g. Reddit data)
- Research trajectories
  - Do we just want to improve on benchmark results?
  - *Real* use-cases

Source: Emily M. Bender, *On the dangers of stochastic parrots*

# Risks

- Potential harms of synthetic language
  - Stereotypes, hate speech
  - Training on synthetic data...
    - With more generated data, we keep training on the generated data as *true*
      - Could degrade the quality of LLMs at scale

Source: Emily M. Bender, *On the dangers of stochastic parrots*

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