

Report 1: Introduction to Large Language Models (LLMs)

Large Language Models (LLMs) are AI systems designed to understand, generate, and manipulate human language with high accuracy. They are based on deep learning architectures, primarily the transformer, which uses self-attention mechanisms to capture semantic relationships and context over long sequences of text.

Training and Architecture

- LLMs are pretrained on massive datasets from diverse sources such as books, websites, code repositories, and forums.
- They learn statistical patterns in language during unsupervised pretraining by predicting the next word or token in text sequences.
- The transformer architecture allows parallel processing of input tokens, with attention layers emphasizing relevant parts of the context.
- Key components include embedding layers converting words to vector representations, self-attention layers for contextual weighting, and feedforward layers for nonlinear transformations.
- During fine-tuning, LLMs are trained on smaller, labeled datasets to specialize in specific tasks or domains.
- Prompt-tuning is an alternative where the LLM learns to perform tasks using few-shot or zero-shot prompts, without model weight changes.

Model Scale and Capabilities

- Modern LLMs typically contain billions to trillions of parameters, enabling generalist capabilities like translation, summarization, question answering, and creative text generation.
- LLMs excel in few-shot learning, performing new tasks with minimal examples.
- Chain-of-thought prompting enhances complex reasoning by breaking tasks into intermediate steps.
- Models like GPT-4, Claude, Gemini, and LLaMA exemplify current state-of-the-art LLMs.

Applications and Limitations

- LLMs power chatbots, virtual assistants, medical documentation, legal analysis, and code generation.
- Despite successes, LLMs can hallucinate, produce biased or unsafe content, and require alignment with human values via human feedback.
- Computational cost and environmental impact remain challenges.
- Ethical use and transparency are critical as LLM deployments grow.