Emergent Abilities of Large Language Models
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Figure 1: What is emergence?

Apes together strong.
Emergence

What is emergence?

Figure 2: Example of Emergence in GPT3 model family
Emergence

Emergence is defined as a property that is observed in an complex entity but not part of it’s constituent. Examples may include consciousness, bird flocking.

For the discussion pertaining to LLMs the authors of Wei et al. [9] define emergence as: An ability that is not present in smaller model, but present in larger models in a way that couldn’t have been predicted by extrapolating the scaling laws.
PaLM [3] beats GPT3 [2] on WiC benchmark, disproving the earlier hypothesis of Decoder-Only Models being bad for the benchmark.

| Model                  | Score |
|------------------------|-------|
| Fine-tuned SOTA        | 76.1  |
| Fine-tuned BERT-Large  | 69.6  |
| GPT-3 Few-Shot         | 49.4  |
| PaLM Few-Shot          | 64.6  |

Table 1: Performance of Models on WiC Benchmark
Motivation

Simply by scaling in number of parameters, training dataset size, and/or training compute, a massive performance boost is observed. A subset of those performances can’t predicted by simply extrapolating the scaling laws.
Emergence in LLMs

- LLMs are scaled majorly in the following dimensions, i.e. Model Size (number of parameters), Total compute need for training (Total number of Floting Point Operations/FLOPs) and Training dataset size.

- Wei et al. [9] explored the emergence behaviors against training compute. No claims are made about achieving emergence at a certain scale. The aim is just to observe the behavior.
Emergence in LLMs

The following tasks were found to be emergent by Wei et al. [9].

Figure 3: Emergent Tasks
A prompting or finetuning technique that is only helpful at a certain scale is also considered emergent [9].

Figure 4: Specialized prompting or finetuning methods as emergence
Discussion

- **Frontier Tasks**
  - Models with their current scale give random performance on tasks such as, “checkmate in one”, “mathematical induction”, “multistep arithmetic” etc.

- **Improving Architecture**
  - Many abilities earlier only seen in larger models, is achieved at a much smaller scale in a later generation. Example LLAMA 3.2 models [8].
  - More study in model architecture and emergence could be the key to unlocking these abilities at much smaller scale.
So, is emergence real?
Limitation

- Srivastava et al. [7] suspect the emergence trends to be an artifact of the metrics being discrete in nature. Wei et al. [9] also have observed the difference between using discrete and continuous metrics, but fail to provide a theory to explain the discrepancy.

- Srivastava et al. [7] prove the hypothesis and provide an explanation. Discrete metrics fail to reliably capture incremental improvements in the smaller models accurately.
Limitation

Using a metric with higher resolution causes emergence trends to disappear [6].

Figure 5: Using Accuracy vs Token-Edit-Distance metric
Limitation

Using more test points (i.e. providing more resolution) also causes emergence trends to disappear [6].

Figure 6: Generating the accuracy graph with more data points
Limitation

Using a continuous metric instead of a discrete metric also causes the trends to disappear (Observed by Wei et al. [9])
So, emergence is just mirage?
Possible mechanism for emergence

- Wei et al. [9] hypothesize, certain tasks may require a model to have layers and parameters beyond a particular threshold (e.g., computation steps, memorization requirements).

- Tasks that are bottlenecked by a particular skill requirement (Monogenic [4]) will appear emergent [4], [5], [1], even when using a continuous metric [4].

- Michaud et al. [4] report most LLM tasks to be Polygenic\(^1\) in nature.

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\(^1\)i.e. dependent on multiple skills who compose additively
Conclusion

- Emergence in LLMs is defined as abilities that appear at scale but unexplainable by scaling laws.
- Scaling Language Models is essential to discover new abilities of models
  - Further study on model architecture would help achieve the emergent abilities at a smaller scale.
- Current evidence for emergence is not enough.
  - The apparent “emergence” can be explained by scaling laws by using a continuous metric.
  - There does exist a strong mathematical model to explain emergence if sighted.
- Schaeffer, Miranda, and Koyejo [6], while criticizing the findings, also encourage further studies on emergence.
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