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Chapter 7

Looking Forward

This thesis opens several promising avenues for future research and applications:

7.1 Future Directions

Theoretically, this thesis emphasizes the central role of factorization – a form of computation decomposition – in learning structures (Chapter 2 and Chapter 3). A promising direction for future research is studying a unified framework for understanding the widespread presence of factorization in handling discrete symbolic interactions. This includes models such as word2vec, tensor factorization, RNNs, and Transformers. Potentially transformers themselves can be interpreted as bi-level factorization models, offering new perspectives on their internal computations.

Alongside theoretical exploration, I am interested in applying these findings for AI transparency and safety. First, how can we use the identified n-gram paths (Chapter 3) to exert structural control over the behaviour of large language models? For example, conducting invariant learning over selected paths [Arjovsky et al., 2019] could help fix unwanted structures that cause biases or undesirable outcomes. Second, we can extend research such as [Chen et al., 2024] by systematically extracting interpretable structures from various LLMs, advancing transparency and trust in this rapidly evolving field. Third, we can apply the active forgetting techniques proposed in this thesis (Part II) to preserve low-resource languages such as Hokkien, supporting decentralized knowledge management systems that could benefit from decoupling embeddings from model

bodies Zhao et al. [2024b], Jacob et al. [2024]. This approach could also enhance epitope link prediction tasks where limited data complicates generalization across epitope groups [Liu et al., 2024a].

These future directions lie in the intersection between theoretical advances and practical implementations, contributing to both the foundational understanding of AI models and their real-world applications in transparent, safe, and inclusive systems.

7.2 Final Thoughts

The equation for building general knowledge engines likely transcends the simplistic notion of *structured + unstructured = intelligence* or scaling both of them. Structured and unstructured representations are merely two states of the engine. They are not the driving forces behind intelligent behaviour.

A more accurate formulation may be:

$$\text{Structuring} \leftrightarrow \text{Destructuring} = \text{Intelligence}$$

where intelligence emerges from balancing the dual forces while maintaining fluidity. Structuring accumulates knowledge by organizing meaningful relations into reusable forms, while destructuring mitigates rigid, outdated, and potentially harmful structures, enabling continuous learning and adaptation in ever-changing reality.

Scaling may indeed be a pathway toward *Artificial General Intelligence* (AGI v1), as digesting vast amounts of data naturally leads to learning more and more complex structures about our world. However, achieving *Artificial Good Intelligence* (AGI v2) requires more than just scaling. It demands plasticity – the ability to discard outdated knowledge structures, regrow new ones, and adapt effectively to new environments. In this view, balancing structuring and destructuring becomes a key hallmark of a truly intelligent system, capable of evolving with the ever-changing realities.

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