Variational quantum natural language processing

'NExt ApplicationS of Quantum Computing' project

Antonio Villalpando Barroso (ICHEC). Email: antonio.villalpando@ichec.ie

Natural language processing has proven one of the most successful branches of machine learning. From machine translation to intent detection, there exist many algorithms able to solve diverse industry problems[1]. These methods usually rely on a distributional approach, using high dimensional word vectors and statistics to read the meaning of corpora and solve specific tasks. Quantum computing can offer a different solution, where not only the distribution of words is accounted, but also their relation, in a more similar way to how we understand language[2]. The structure of entanglement in quantum mechanics is similar to that of a pregroup grammar within compact closed category theory[3]. In that sense, parts of speech are mapped to categories, and we can make an analogy to the Hilbert space where quantum states live. Words are then composed using tensor products to form sentences, in the same way qubits can be tensorized to create many-body quantum systems. These systems can be then implemented in quantum computers, and we can train NLP models using hybrid classical-quantum algorithms within the capabilities of NISQ devices[4]. Sentences are represented by tensor states after applying some contractions, and techniques of many body physics can be applied. Applicability of this approach to more complex NLP algorithms like the Transformer is also considered.

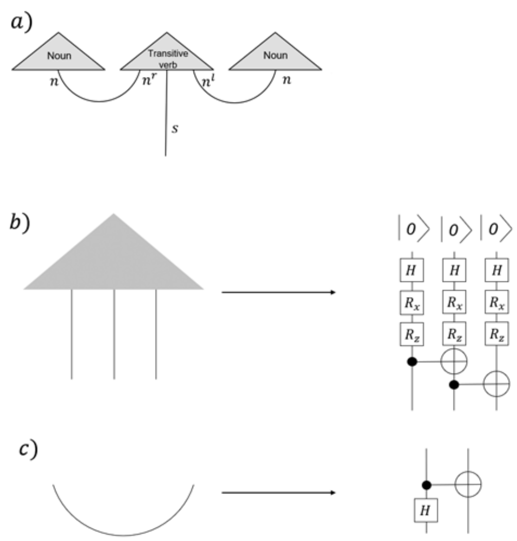

Figure 1: a) The tensor state representing a sentence with the contracted legs. The dimensionality of the resulting state is given by s. b) A ket representation in the diagrammatic and circuit forms. c) A cup represents the contraction of categories within the sentences, and in a circuit representation it is similar to the quantum teleportation protocol.

(1) Young, T.; Hazarika, D.; Poria, S.; Cambria, E. *ieee Computational intelligenCe magazine* **2018**, *13*, 55–75.

(2) Coecke, B.; de Felice, G.; Meichanetzidis, K.; Toumi, A. *arXiv preprint arXiv:2012.03755* **2020**.

(3) Lambek, J. *The mathematical intelligencer* **2006**, *28*, 41–48.

(4) Bharti, K.; Cervera-Lierta, A.; Kyaw, T. H.; Haug, T.; Alperin-Lea, S.; Anand, A.; Degroote, M.; Heimonen, H.; Kottmann, J. S.; Menke, T., et al. *arXiv preprint arXiv:2101.08448* **2021**.