Ph.D. Position

Design and Hardware Implementation of Coding and Signal Processing for 5G/6G and beyond: Machine Learning for Communications and Terabit per second decoding

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Error correcting codes (ECC) are required for controlling errors in data transmitted over noisy channels. Depending on the application (ie. mobile communications, satellite communications...), several constraints have to be considered. Among them, one can cite the following:

- High throughput
- Low power consumption
- Extremely low error rate

At the ISIP Lab, under the supervision of Prof. Warren Gross, we are looking at defining ECC and their associated hardware architectures for the next generations of communications standards.

In previous years, we notably built expertise in designing fast hardware architectures for polar decoders, enabling the use of polar codes in the fifth generation of cellular mobile communications (5G).

1 More details on potential projects

1.1 Terabit per second decoders

For polar codes several decoding algorithms can be considered. The state-of-the-art Successive Cancellation List (SCL) algorithm can reach a throughput (T/P) of 2 Gbps [1] with a list-size of two. Using the belief propagation (BP) algorithm, polar codes can be decoded with a 10 Gbps T/P [2]. Finally, considering the SC algorithm and by fully-unrolling and deeply-pipelining the hardware architecture, a 20 Gbps T/P can be achieved [3].

However, the state-of-the-art is still far away from reaching a throughput close to a terabit per second since it could be required by applications in the relatively near future.
Reaching such a T/P is a challenging task and will require innovation at several levels of the design stack (algorithms and implementation)

1.2 Machine learning for coding and communications

Deep neural networks has revolutionized machine learning by showing a remarkable performance in extracting and representing high-level abstractions in complex data. Adapting deep learning techniques to solve conventional problems on channel coding and communications in general is currently underway in our lab.

Recently, it was shown that deep learning methods can be used to improve a BP decoder [4]. This Neural BP decoder can either be used to improve the decoding performance or to reduce the computational complexity. In [5], by assigning trainable weights to the edges of a CRC-polar concatenated factor graph, up to 0.4 dB error-correction performance improvement with respect to the state of the art, can be observed.

Finally at the ISIP Lab, we are convinced that machine learning can be a useful tool for solving hard problems encountered by the coding research community.

2 Required profile

- Master degree in Electrical Engineering or equivalent, or clear evidence of research potential for entry to the PhD program without a Masters
- Strong experience in either:
  - Error correction codes
  - Digital hardware design
- Strong competence in implementing algorithms in software (C/C++/Python)
- Good writing skills

3 How to apply

Please send an e-mail to Professor Gross with the following information:

- Detailed CV
- University transcripts
- A copy of the master thesis and/or scientific paper if available
- A list of personal references
- A motivation letter

Applications for PhD programs starting in Fall 2019 will be welcome until 2018/12/15.

References

[1] D. Kim and I. Park, "A fast successive cancellation list decoder for polar codes with an early stopping criterion," *IEEE Transactions on Signal Processing*, vol. 66, no. 18, pp. 4971–4979, Sept 2018.

[2] S. M. Abbas, Y. Fan, J. Chen, and C. Tsui, "High-throughput and energy-efficient belief propagation polar code decoder," *IEEE Transactions on Very Large Scale Integration (VLSI) Systems*, vol. 25, no. 3, pp. 1098–1111, March 2017.

[3] P. Giard, G. Sarkis, C. Thibeault, and W. J. Gross, "Multi-mode unrolled architectures for polar decoders," *IEEE Transactions on Circuits and Systems I: Regular Papers*, vol. 63, no. 9, pp. 1443–1453, Sept 2016.

[4] E. Nachmani, E. Marciano, L. Lugosch, W. J. Gross, D. Burshtein, and Y. Beery, "Deep learning methods for improved decoding of linear codes," *IEEE Journal of Selected Topics in Signal Processing*, vol. 12, no. 1, pp. 119–131, Feb 2018.

[5] N. Doan, S. A. Hashemi, E. N. Mambou, T. Tonnellier, and W. J. Gross, "Neural belief propagation decoding of crc-polar concatenated codes," *arXiv preprint arXiv:1811.00124*, 2018.