Master Thesis / Internship:
Regularity and Invertibility of BregmaNets

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Level: Master 2 / 3rd year of engineering school
Gratuity: $\simeq$ 540 euros/month

Keywords: Deep learning; Lipschitz regularity; Robustness; Invertible neural networks

Description Bregman Neural Networks [1] (BregmaNets) are a novel class of neural networks, reminiscent of ResNets, additionally involving the inverse of the activation function. Experimentally, they have shown more robust prediction performance than their standard counterparts. However, their stability has not yet been theoretically grounded. This internship proposal aims to tailor the latest advances in the study of the Lipschitz regularity of neural networks in order to i) elucidate the added robustness of BregmaNets and ii) develop invertible BregmaNets. The first part will be devoted to the design of an upper bound on the Lipschitz constant by hinging on the compositional form of BregmaNets [2]. A refined estimation through a PyTorch toolbox will also be considered. The second part will focus on the conditions permitting to enforce the invertibility of BregmaNets. To this purpose, the previous results on the Lipschitz continuity will be of upmost importance in order to extend the results from ResNets [3] to BregmaNets.

Expected results

- Bibliographical study on the Lipschitz regularity of neural networks
- Derivation of an upper-bound of the Lipschitz constant of BregmaNets
- Design of a PyTorch toolbox to analyze the sensitivity of BregmaNets
- A publication in a leading journal or conference could be considered depending on the results

Candidate profile A strong background in mathematical analysis is required. Python and PyTorch skills are welcomed.

References

[1] Frecon, J., Gasso, G., Pontil, M. & Salzo, S. (2022). Bregman Neural Networks. *Proceedings of the 39th International Conference on Machine Learning*. 162:6779-6792.

[2] Gupta, K., Kaaka, F., Pesquet-Popescu, B., Pesquet, J.-C. & Malliaros, F.D. (2022) Multivariate Lipschitz Analysis of the Stability of Neural Networks. *Front. Sig. Proc.*. 2:794469.

[3] Behrmann, J., Grathwohl, W., Chen, R., Duvenaud, D. & Jacobsen, J. (2019). Invertible Residual Networks. *Proceedings of the 36th International Conference on Machine Learning*. 97:573-582