CLASSIFICATION OF CEREBRAL MICROEMBOLI : LATENT SPACE ANALYSIS AND UNCERTAINTY QUANTIFICATION FOR SOFTWARE INTEGRATION INTO A TRANSCRANIAL DOPPLER MEDICAL DEVICE

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Transcranial Doppler (TCD) is an ultrasound technology that enables the monitoring of blood flow velocities in the cerebral arteries at specific points. Another, less widesplread application of great interest is cerebral emboli monitoring, as gaseous or solid particles circulating in the cerebral blood system are one of the main risks for stroke. TCD is the only tool that enables their detection during circulation, paving the way for stroke prevention and a better understanding of the origins of emboli. However, TCD is not widely used for this purpose, potentially due to a lack of expertise in interpreting TCD signals.

Our team has been collaborating with Atys Medical, a company based in Lyon that designs and produces portable and robotized TCD devices. Our goal is to develop classification models to assist clinicians in handling these signals. These enriching exchanges with industrial and clinical partners have led us to address a variety of methodological challenges, such as semi-automatic annotation, hybrid models, model compression, contrastive learning, and uncertainty quantification. These advancements have also been integrated into the company's software, allowing our work to reach clinicians.

In particular, two examples will illustrate these bidirectional transfers. First, latent space analysis of unsupervised classification models has enabled better understanding of the data and the development of a tool for semi-automatic annotation. This not only improves data annotation efficiency[1] but also introduces an alternative method for data visualization that can help uncover trends. We pushed it by weakly constraining latent space design[2] by adding emboli position in cardiac cycle using contrastive learning, which is promising to integrate metadata while keeping unsupervised distribution. Second, as the need for uncertainty quantification to support decision making as emerged, we questioned the stability of Monte-Carlo dropout with noisy labels and showed its better reliability when trained with noisy-labels robust loss functions.

[1] Y. Vindas, B. K. Guépié, M. Almar, E. Roux, and P. Delachartre, "Semi-automatic data annotation based on feature-space projection and local quality metrics: An application to cerebral emboli characterization," *Medical Image Analysis*, vol. 79, p. 102437, Jul. 2022, doi: 10.1016/j.media.2022.102437.

[2] M. Dupouy, Y. Vindas, M. Almar, B. K. Guépié, and P. Delachartre, "Weakly-Supervised Semantic Space Structuring: Cardiac Cycle Position for Cerebral Emboli Visualization Using Contrastive Learning," in *2025 IEEE 22nd International Symposium on Biomedical Imaging (ISBI)*, Apr. 2025, pp. 1–4. doi: 10.1109/ISBI60581.2025.10981113.