The Hong Kong University of Science and Technology

Department of Mathematics

PhD THESIS EXAMINATION

Differential Privacy for Inference in Clinical Studies

By

Miss Xiaowen FU

ABSTRACT

Critical challenges in clinical studies include the constraints of privacy protection and inherent data complexities such as selection bias, high-dimensional settings, and multimodal deep learning. First, we explore the inference on extrema parameters in clinical studies, which is crucial for identifying significant health outcomes. We develop a privatized parametric bootstrap method tailored for the exponential family of distributions, which corrects selection bias under differential privacy. This method efficiently constructs valid lower confidence limits for extrema parameters, demonstrated through real-world clinical applications. Second, we extend the work to a high-dimensional linear regression case, which is challenging due to sparsity and high-dimension constraints. We present an integration of differentially private de-biased lasso with bootstrap techniques to address selection biases in observational studies. This approach enhances statistical efficiency and maintains privacy, enabling the construction of reliable lower confidence limits even in high-dimensional data scenarios. Lastly, we focus on the application of differential privacy to multimodal EEG data analysis for disease diagnosis, specifically for detecting Freezing of Gait in Parkinson's disease. We introduce a novel multimodal deep learning algorithm that processes EEG data similarly to text in NLP models and treats physiological signals as images in Vision Transformers, incorporating cross-attention mechanisms. We also prompt a novel feature-level privacy protection scheme specifically designed for the multimodal learning framework. This scheme optimally allocates randomness between dropout mechanisms and Laplacian noise injection for element-wise features. The effectiveness of our method is demonstrated by its improvement in utility compared to the state-of-the-art (SOTA) methods, while simultaneously protecting privacy.

Date : 7 August 2024, Wednesday

Time : 3:00 pm

Venue : Room 4475 (Lifts 25-26)

***Thesis Examination Committee*:**

Chairman	**:**	**Prof. Pak Wo LEUNG, PHYS/HKUST**
Thesis Supervisor	**:**	**Prof. Yang XIANG, MATH/HKUST** **Prof. Xinzhou GUO, MATH/HKUST**
Member	**:**	**Prof. Shiqing LING, MATH/HKUST**
Member	**:**	**Prof. Zhichao PENG, MATH/HKUST**
Member	**:**	**Prof. Jiashuo JIANG, IEDA /HKUST**
External Examiner	**:**	**Prof. Hanquan WANG, Yunnan University of Finance & Economics**

(Open to all faculty and students)

The student's thesis is now being displayed on the reception counter in the General Administration Office (Room 3461).