Research Profile

Kit Ian Kou, Associate Professor

Department of Mathematics, University of Macau

RESEARCH

Theoretical Foundations

Prof. Kou's research in pure mathematics is centred on extending the boundaries of hypercomplex analysis. A flagship achievement in this area is her work on the Paley-Wiener theorem in the Clifford analysis setting, published in the *Journal of Functional Analysis* [1]. This seminal paper successfully generalizes a fundamental result in Fourier analysis—characterizing functions whose Fourier transforms have compact support—to the context of Clifford algebra-valued functions. The result provides an essential theoretical tool for higher-dimensional signal processing and remains a cornerstone contribution to the field.

Building on this foundation, she has also made significant contributions to the generalizations of the Fueter Theorem. In a highly-cited 2002 paper co-authored with Tao Qian and Frank Sommen, Kou established new results for constructing monogenic functions from holomorphic functions, proving conditions under which induced functions remain monogenic—a result particularly relevant when the space dimension is odd [2]. Together, these works exemplify her ongoing program of translating classical harmonic analysis into the hypercomplex domain.

Applied Signal & Image Processing

Professor Kou's applied research leverages the power of quaternion and Clifford algebras to revolutionize how color images and high-dimensional data are processed. By encoding the red, green, and blue channels of a color pixel as a single quaternion, her methods preserve the inherent color structure of visual data—an advantage over traditional approaches that process each channel separately. This foundational insight has led to state-of-the-art algorithms across several domains:

Foundational Theory for Color Face Recognition

A landmark contribution in this area is her 2016 *IEEE Transactions on Image Processing* paper on quaternion collaborative and sparse representation for color face recognition [3]. This work was the first to provide rigorous theoretical guarantees for using quaternion representations in face recognition, establishing the mathematical conditions under which quaternion-based collaborative and sparse representation methods (QCRC and QSRC) are effective. Prior to this, even the original real-valued methods lacked such theoretical foundations. The paper demonstrates how modeling each color image as a single quaternionic signal naturally preserves the structural correlation among color channels—a limitation of grayscale-based approaches that treat each channel separately. Comparisons on benchmark databases consistently show the superiority of these quaternion methods for both color face recognition and image reconstruction. This line of work has been extended to quaternion PCA for improved color face recognition [4].

Advanced Edge Detection

Professor Kou has made significant contributions to color edge detection, a fundamental task in computer vision. Her work on phase-based edge detection algorithms, published in *Mathematical Methods in Applied Sciences* (2018), introduced two novel methods: quaternion differential phase angle and quaternion differential phase congruency [5]. These methods leverage the quaternion analytic signal to extract structural information from images, consistently outperforming competing methods in terms of peak signal-to-noise ratio (PSNR) and structural similarity index

measure (SSIM). More recently, she developed the quaternion Hardy filter (QHF) for robust color edge detection (2022), which achieves a minimum PSNR improvement of 2.3% and SSIM improvement of 30.2% on benchmark databases while offering tunable parameters for handling different noise levels [6]. This work has been extended to lane detection for autonomous driving applications.

Image Recovery and Matrix Completion

A central theme of her work is developing efficient methods to reconstruct missing or corrupted visual data. She pioneered low-rank quaternion matrix completion techniques that significantly outperform conventional methods in recovering color images [7]. Her 2021 *IEEE Transactions on Image Processing* paper on low-rank quaternion matrix completion provides a rigorous algorithmic framework for color image recovery. Most recently, she has developed an approximate quaternion SVD method (CQSVD-QQR) that reduces computational complexity while maintaining accuracy for medical image recovery, published in *Applied Mathematics and Computation* (2025) [8].

Medical Image Analysis

A rapidly growing area of her research involves applying quaternion methods to medical imaging. Her work on low-rank quaternion matrix completion has been successfully applied to color medical images, demonstrating superior performance over state-of-the-art methods [7]. The approximate quaternion SVD method (CQSVD-QQR) is specifically designed to make these algorithms scalable for large-scale medical image data while preserving accuracy [8].

References

[1] Kou, K. I., & Qian, T. (2002). The Paley-Wiener theorem in R^n with the Clifford analysis setting. *Journal of Functional Analysis*, 189(1), 227-241.

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[3] Zou, C., Kou, K. I., & Wang, Y. (2016). Quaternion collaborative and sparse representation with application to color face recognition. *IEEE Transactions on Image Processing*, 25(7), 3287-3302.

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[7] Miao, J., & Kou, K. I. (2021). Color image recovery using low-rank quaternion matrix completion algorithm. *IEEE Transactions on Image Processing*, 31, 190-201.

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Online Publication Profiles

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