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HYPERBOLIC WINDOWED LINEAR CANONICAL TRANSFORM OF QUATERNION SIGNALS

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Abstract. This paper investigates the application of the Quaternion Hyperbolic Windowed Linear Canonical Transform (QHWLCT) to the analysis of two-dimensional quaternion-valued signals These signals are defined over an open rectangle in the Euclidean plane $\mathbb{R}^2$ and are endowed with a hyperbolic measure The Linear Canonical Transform (LCT), a versatile integral transform with broad applications in signal processing, optics, and communications, serves as the foundational framework We introduce a novel extension by integrating quaternion algebra, a localized windowing function, and by replacing the conventional complex exponential (Euclidean plane wave) with a hyperbolic relativistic plane wave kernel This synthesis yields a more powerful analytical tool capable of effectively processing multidimensional signals with intricate structural properties We also establish the fundamental properties of the proposed QHWLCT Furthermore, we derive and prove its core theorems, including the orthogonality relation, a rigorous inversion formula, and a Heisenberg-type uncertainty principle that provides a lower bound for the joint time-hyperbolic frequency resolution An example is also provided at the end of the paper.

1. Introduction

The analysis of two-dimensional signals plays a crucial role in a wide range of scientific and engineering applications, including image processing, biomedical imaging, computer vision, and optical systems Traditional time-frequency representations, such as the Fourier Transform (FT), Short-Time Fourier Transform (STFT), and Wavelet Transform (WT), have been extensively used to study the local and global features of signals However, these methods often face limitations in achieving high-resolution analysis, particularly when dealing with non-stationary or multidimensional signals To address

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