Interferometric Image Reconstruction using Closure Invariants and Machine Learning

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Interferometric imaging, a crucial tool for projects like the Event Horizon Telescope (EHT), faces formidable challenges from distortions in amplitude and phase affecting incoming wavefronts. Calibration, the process of aligning signals coherently, is vital for image reconstruction, especially in Very Long Baseline Interferometry (VLBI) scenarios like the EHT. In VLBI, where elements are separated by Earth-scale distances, challenges such as sparse aperture coverage, low signal-to-noise ratio, calibration-related issues, and limitations in imaging algorithms emerge, particularly in extreme cases like the EHT.

The EHT made history by releasing the first event horizon scale images of black holes in M87 [1] and our Milky Way [2]. While independent confirmations have validated the results, the groundbreaking nature of such experiments necessitates additional verification using orthogonal approaches to eliminate potential systematic biases. The demanding calibration and imaging conditions in VLBI provide an opportune environment for developing innovative image reconstruction algorithms, a focus of our work.

To address challenges in calibration, we utilize calibration-independent interferometric measurables known as closure invariants, including closure phases and closure amplitudes [3]. These measures remain invariant to antenna-based calibration and errors, encapsulating genuine morphological information about the objects of interest. Recent advancements have seen different classes of closure invariants unified under a single formalism, providing a comprehensive and independent set [4, 5].

Our approach applies this unified framework of calibration-independent closure invariants to interferometric image reconstruction. Leveraging the capabilities of Machine Learning (ML), we have achieved promising initial results with simple ML algorithms [6]. Ongoing work involves the exploration of more advanced ML models and a detailed comparison with conventional approaches. By focusing on closure invariants and incorporating Machine Learning, our work offers an independent and complementary solution to existing interferometric reconstruction approaches. Moreover, it provides valuable insights into the mapping of closure invariants to morphological information, pushing the boundaries of interferometric imaging capabilities and offering new avenues for exploration in the field.

References

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