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Optical Flow for Wave Characterization in a 2D Water Flume Using Video Analysis: A Cutting-Edge Tool for Coastal Monitoring

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Coastal monitoring is a rapidly evolving field essential for understanding meteorological and marine conditions, which in turn supports the development of effective strategies for managing coastal areas. This necessity is increasingly critical given the challenges posed by climate change, rising sea levels, and extreme weather events. Among the tools available, video surveillance, combined with advanced machine learning and computer vision techniques, has emerged as a powerful method. It offers detailed spatial and temporal data, essential for analyzing tidal phases, wave parameters, and storm dynamics across extensive geographic areas.

In this study, we propose an innovative integration of optical flow techniques with video analysis to accurately quantify wave motion parameters. Optical flow, which evaluates object displacement between video frames, is applied to determine wavelength, wave height, and flow velocity. This approach is particularly suited for storm conditions where traditional methods face logistical and financial constraints. Our method enables high-precision, real-time measurements vital for analyzing coastal processes during extreme events. To ensure reliability, the results are cross-validated with in situ instrument data and verified through environmental reconstructions using point clouds and ground control points. This dual-validation strategy minimizes video distortions and enhances measurement accuracy, aligning optical flow results with physical realities.

The proposed system has been tested in a controlled environment at the Coastal Engineering Laboratory of the University of Palermo. A two-dimensional laboratory flume simulated different coastal conditions, ranging from calm waters to storm-like scenarios, ensuring the robustness and adaptability of the methodology. By leveraging optical flow techniques with video surveillance, this approach promises a transformative impact on coastal monitoring, providing continuous, automated, and cost-effective data collection even in remote or inaccessible locations. It offers a scalable alternative to conventional methods, which often demand expensive installations and extensive manpower. The potential of this method to deliver high-quality real-time data, represent a significant advancement in coastal management and environmental monitoring.