Creating a Custom Dataset and AI Model for Predicting Sail Deformations: Integrating Computer Vision for Data Extraction and Machine Learning for Predictive Analysis

Sailboats rely heavily on the precise adjustment of sails to achieve optimal performance under varying environmental conditions. The relationship between sail input controls and the resulting sail shape is complex, nonlinear, and not yet fully understood. While computational fluid dynamics (CFD) and manual methods exist to analyze sail performance, they are time-intensive and lack real-time applicability.

Professional sailing teams require real-time sail shape prediction capabilities in their simulation environments. Machine learning presents a promising solution, potentially enabling accurate 3D sail shape predictions based on datasets that combine input controls, environmental factors, and sail shape representations.

A key challenge lies in accurately defining the sail shape and linking it to input controls and environmental factors. Sail shape is traditionally measured through costly, manual processes, making large-scale data collection impractical. Furthermore, there is a lack of datasets that integrate sail input controls, environmental conditions, and visual sail shapes for predictive modeling using advanced machine learning techniques. This presents a clear gap that modern computer vision techniques can fill, offering potential solutions for automated, real-time sail shape analysis.

This project addresses these challenges through a comprehensive data collection and analysis pipeline. The process begins with capturing sail photographs during active sailing conditions (see Fig. 1), while simultaneously recording input control settings and environmental variables. An automated computer vision pipeline was developed to extract sail splines from these images (see Fig. 2), enabling the generation of numerical representations of sail shapes. This dataset will then be used to train a neural network capable of predicting sail shapes based on input controls and environmental factors.

This project provides compelling evidence that both core challenges - real-time sail shape prediction and automated data collection - can be effectively addressed through the integration of machine learning and computer vision techniques.

opt 1 The successful implementation demonstrates that complex sail dynamics can be captured and predicted using modern computational methods, offering a significant advancement over traditional CFD and manual approaches.

opt 2 The implications of this research extend beyond theoretical validation. By establishing a scalable framework for sail shape analysis, this work paves the way for practical applications in competitive sailing, sail design optimization, and training simulations.