

An Intelligent Framework for Multi-Scenario Fabric Selection in Cycling Apparel: A User-Expert Dual-Driven Approach

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Abstract

Traditional evaluation of cycling trouser fabrics employs fixed-weight methods, failing to address the diverse performance demands of dynamic cycling scenarios. To overcome this limitation, this study developed and validated an intelligent scoring system using a “user-expert” dual-driven dynamic weight optimisation strategy. A dynamic weighting scheme was first constructed by integrating the Analytic Hierarchy Process (AHP) with user survey data. To mitigate data scarcity, a Generative Adversarial Network (GAN) was utilised to augment the dataset. Subsequently, a random forest regression model, integrated with a fuzzy logic engine, was employed to dynamically adjust performance weights (abrasion resistance, moisture permeability, air permeability) based on scenario inputs. The model achieved a coefficient of determination (R^2) of 0.924 on the training set and an average R^2 of 0.893 on the test set. Further validation demonstrated a prediction error of $\leq 5.2\%$ for new fabrics and maintained R^2 values above 0.85 under hyperparameter sensitivity analysis, indicating strong generalisation and robustness. This research provides a validated, data-driven framework for fabric selection in customised clothing and introduces a novel paradigm for the performance-based design of advanced technical textiles.

Keywords: Cycling trousers; Fabric Evaluation; Digital Evaluation; Data-driven; Intelligent Scoring System

1 Introduction

The engineering of high-performance functional textiles is a cornerstone of modern sportswear design, aiming to optimise the complex interplay between the user, the garment, and the environment. In cycling, this relationship is particularly critical. As a key interface between the athlete and the bicycle, the fabric choice for cycling trousers demonstrably affects not only user comfort and durability but also measurable athletic performance [1]. The underlying physical

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properties governing this performance—such as abrasion resistance, moisture permeability, and air permeability—are therefore essential considerations, especially in long-duration, high-intensity conditions [2-4]. These properties directly influence the skin-fabric micro-climate, which in turn affects thermoregulation through physiological responses like skin temperature and transepidermal water loss [5].

However, a fundamental challenge lies in the inherently contradictory nature of these performance demands. For instance, high abrasion resistance, crucial for durability, often requires a dense fabric structure that can impede moisture and air permeability, which are vital for thermal comfort [6]. The conventional approach to fabric evaluation is ill-equipped to resolve these conflicts. Existing research and commercial products frequently rely on static, fixed-weight methods or are optimised for a single performance metric [7-8]. This static approach fails to adapt to dynamic cycling scenarios, as a single set of weights cannot capture the necessary performance trade-offs required in different contexts. Consequently, with fabric selection often relying on empirical judgment, a systematic framework for multidimensional, synergistic analysis that provides a quantitative basis for decision-making is notably absent in the current literature.

This study addresses this critical gap by developing and validating a data-driven, intelligent evaluation model. Our approach is distinguished by its ability to dynamically optimise performance weights based on specific cycling scenarios and user preferences. By systematically testing nine commercial fabrics and constructing a “user-expert” driven scoring system, this research aims to provide a quantitative and adaptable framework to overcome the limitations of static, one-size-fits-all assessment methods. Ultimately, this work aims to provide robust data support for the scientific design and functional optimisation of cycling trousers, paving the way for intelligent sports equipment development.

2 Methodology

2.1 Materials and Data Augmentation

Nine commercially available warp-knitted and weft-knitted cycling trouser fabrics were selected as the primary experimental materials (see Table 1). These samples were chosen to represent a diverse range of compositions (Polyester/Spandex blends), weights, and structural properties prevalent in the market, ensuring the model’s foundational data is comprehensive. All samples were conditioned for 24 hours under standard atmospheric conditions ($20\pm 2^\circ\text{C}$, $65\pm 4\%$ RH) before testing.

To address the inherent challenge of data scarcity in materials science, which can limit the generalisation capability of machine learning models, a Generative Adversarial Network (GAN) was employed to create 20 sets of high-fidelity virtual samples. The GAN methodology was specifically chosen over simpler interpolation techniques (e.g., SMOTE) for its superior ability to learn the complex, non-linear distributions of the original data, thereby generating more realistic virtual instances. The distributional integrity of the augmented dataset was rigorously validated using the Kolmogorov-Smirnov (K-S) test, which confirmed that no statistically significant difference existed between the real and generated data distributions ($p > 0.05$ for key variables), thus ensuring the reliability of the augmented data for subsequent model training.