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Application of multivariate statistical techniques in textile research

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Introduction

Multivariate statistical techniques analyze complex datasets containing multiple variables simultaneously. In textile research, these methods are used to optimize manufacturing processes, objectively assess fabric properties, classify materials, and ensure quality control across the supply chain.

Key multivariate methods and their applications in textiles include:

Principal Component Analysis (PCA)

What it does: Reduces the dimensionality of large, highly correlated datasets into fewer, uncorrelated principal components, capturing the maximum possible variance.

Textile application: Used in the objective evaluation of fabrics. For instance, datasets with dozens of mechanical or tactile measurements (like bending, shear, and surface properties) can be reduced to a few core components, allowing researchers to evaluate fabric stiffness, drape, and tailorability at a glance.

Cluster analysis and discriminant analysis

What it does: Cluster analysis groups data points based on similarities, while discriminant analysis builds predictive models to classify observations into predefined categories.

Textile application: Used for the classification and forensic analysis of fibers. Researchers apply these techniques to spectroscopic and chromatographic data (such as FT-IR spectra) to reliably distinguish between different fiber types (e.g., classifying lyocell, polyester, and viscose blends) or trace the origins of identical-looking synthetic yarns.

Partial Least Squares (PLS) & PLS-Discriminant Analysis (PLS-DA)

What it does: Finds the fundamental relations between two matrices (predictors and responses) and is exceptionally powerful when dealing with collinear and noisy data.

Textile application: Widely utilized in on-site quality control and chemical analysis. For example, combining portable Near-Infrared (NIR) sensors with PLS-DA allows manufacturers to quickly identify defective dyed garments or rapidly quantify material composition.

Multivariate Statistical Process Control (MSPC)

What it does: Monitors industrial processes by tracking multiple quality features at the exact same time, often relying on Mahalanobis distance or Hotelling's \(T^{2}\) control charts.

Textile Application: Utilized in real-time defect detection during fabric weaving. It integrates various texture features to spot weaving anomalies swiftly without manually stopping the loom.

Design of Experiments (DoE) with multivariate optimization

What it does: Evaluates the individual and combined impact of multiple independent variables (e.g., temperature, time, chemical concentration) on a set of dependent variables or outcomes.

Textile application: Highly effective in textile wet processing (dyeing, bleaching, and wastewater treatment). Researchers use DoE to mathematically model and optimize complex processes, such as removing chemical oxygen demand (COD) from textile effluents while minimizing treatment time and resources.

The application of these techniques transitions textile research away from time-consuming, subjective human evaluation into a standardized, highly accurate, and data-driven discipline.

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Conflicts of interest

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