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Research on the Sorting System of Used Textiles Based on Near Infrared Spectroscopy

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ABSTRACT
With the global production of used textiles surging, China's annual output reaches 26 million tons, while the recovery rate is only around 20%. Physical, chemical, and biological methods are inadequate: physical methods lack sufficient separation accuracy for blended fibers, chemical methods involve high energy consumption and pollution risks, and biological methods face bottlenecks like long degradation cycles and low efficiency. Therefore, we have developed a used textile sorting system based on near-infrared spectroscopy technology. By integrating high-precision spectral acquisition, deep learning algorithms, and FPGA real-time control technology, we have addressed the industry pain points of low sorting efficiency and difficulty in identifying blended fibers.
The system has constructed a core architecture of "data acquisition - spectral analysis - intelligent recognition", which collaboratively achieves high-precision and high-efficiency identification of used textiles. The data acquisition module adopts the Ocean Insight HDX series spectrometer (with a 250-1200nm wavelength range), combined with a 6-channel annular fiber optic probe array. Through integrating dark current compensation technology and real-time wavelength calibration (based on the NIST SRM-2036 standard plate), it achieves an ultra-high spectral resolution of 0.3nm and a signal-to-noise ratio of >40dB, providing high-fidelity data support for subsequent analysis. The spectral analysis module innovatively builds a hybrid model combining an autoencoder and a multi-layer perceptron (MLP). It gradually compresses 1024-dimensional original spectral data and extracts key features through a 3-layer encoder (256D → 128D → 64D), then completes feature mapping and category determination via a classifier with a 64D → 32D → 16D structure, and finally accurately outputs material identification results. The intelligent recognition module uses FPGA as the control core to realize real-time response of data processing and recognition instructions. Combined with the SG90 servo mechanism sorting device, it achieves millimeter-level positioning accuracy, with a response delay of ≤10ms for control instructions issued by FPGA, ensuring the efficient coordination of identification and sorting actions.
Experimental results show an average accuracy of over 95% (96% for pure cotton, 94% for synthetic fibers, 95% for blended fibers) and compliance with the 2024 industry standard (≥90%). With a 3-second single-item processing time and a continuous capacity of 10 items per minute, it offers a low-cost, high-precision, non-destructive intelligent solution for laboratory-scale and small-scale used textile recycling.