

Graph Neural Network and Multi-Objective Optimization for Personalized Cosmetic Recommendation

Sıla Kaya, Süleyman Güzel, Başak Kasapçopur and Gülçin Dinç Yalçın

Eskişehir Technical University
Department of Industrial Engineering, Türkiye
sila35kaya@gmail.com

Abstract

This study proposes an evidence-based decision support system for personalized cosmetic product recommendation by integrating a multi-relational graph neural network with multi-objective optimization. The primary contribution of the study lies in modeling ingredient interactions not only through data-driven patterns but also by incorporating evidence-based weighting derived from dermatological literature. Ingredient interactions are represented as a heterogeneous graph, where each edge encodes synergy, antagonism, or toxicity relationships. Unlike conventional approaches, each interaction is weighted using a combination of effect (label) and confidence scores, systematically derived from the Oxford Centre for Evidence-Based Medicine (OCEBM) hierarchy. This formulation enables the model to distinguish between strong clinical evidence and weaker mechanistic assumptions, thereby improving the reliability of learned representations. A modified DECAGON architecture is employed to learn continuous-valued interaction scores across multiple relation types, allowing the model to capture complex and co-existing relationships between ingredient pairs. The learned interaction scores are subsequently integrated into a multi-objective optimization framework that maximizes ingredient compatibility while constraining safety risks and minimizing budget deviation. The proposed system generates Pareto-optimal skincare routines tailored to user-specific skin types and concerns. Experimental results demonstrate that the approach effectively balances conflicting objectives while providing reliable and interpretable recommendations. This work contributes to the literature by combining evidence-based modeling with graph learning and optimization, offering a robust and explainable framework for cosmetic recommendation systems.

Keywords

Graph Neural Networks; Multi-Objective Optimization; Decision Support Systems; Personalized Recommendation; Evidence-Based Modeling

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