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Research on Optimization of Water Heater Marketing Strategies Based on User Behavior Analysis and Event Recognition

Lintao Zhang[1]
Anhui University of Finance and Economics, Bengbu, China-233030
Email address: 2384570446@qq.com

Abstract—*With the rapid development of smart home technology, the water heater, as an essential household appliance, has seen its intelligent upgrading and precision marketing become a key industry focus. Traditional water heater products often lack an in-depth understanding of users' personalized needs in both functional design and marketing strategies, leading to suboptimal user experiences and low market responsiveness. This paper proposes a hybrid model based on Transformer and Long Short-Term Memory (LSTM) networks to deeply mine user water usage behavior data and identify specific usage events. By constructing multi-dimensional user profiles, personalized marketing strategies are formulated accordingly. Experimental results demonstrate that the proposed model outperforms traditional methods in terms of accuracy, sensitivity, and specificity in user behavior recognition, effectively supporting water heater enterprises in product optimization and market promotion decisions. This study provides a feasible technical pathway and practical reference for user behavior analysis and precision marketing in the smart home industry.*

Keywords— *User behavior analysis; event recognition; Transformer; LSTM; marketing strategy optimization; smart home.*

I. INTRODUCTION

The smart home market has demonstrated rapid growth in recent years, with water heaters, as essential household energy-consuming devices, seeing intelligent upgrades and personalized services become a core direction for industry development. However, existing water heater products generally suffer from an inadequate understanding of user behavior and overly generalized marketing strategies in both functional design and market promotion, which constrains the enhancement of user experience and product competitiveness. With the advancement of big data and artificial intelligence technologies, in-depth analysis based on user behavior data offers novel approaches to address these challenges.

This study leverages behavioral data from water heater users in smart home environments. By employing a hybrid Transformer and LSTM model, it achieves high-accuracy identification of water usage events such as bathing and handwashing. Furthermore, by integrating multi-source information including user demographics (e.g., region, age, gender), it constructs accurate user profiles to provide data-driven support for enterprises in formulating differentiated and personalized marketing strategies. This research not only contributes to enhancing the intelligent capabilities of water heater products but also holds significant theoretical and practical implications for promoting the digital transformation of the entire home appliance industry.

II. RELATED WORK

A. User Behavior Analysis Methods

User behavior analysis has emerged as a significant research focus within the smart home domain. Early research primarily employed traditional machine learning methods, such as Naïve Bayes and Support Vector Machines (SVM). While these approaches achieved certain results in specific scenarios, they often exhibited limitations including low recognition accuracy and poor generalization capability when dealing with complex, non-stationary user behavior sequences. In recent years, deep learning models have been widely adopted for user behavior analysis due to their powerful feature extraction and sequence modeling capabilities. For instance, Kaur et al. proposed a stacked model based on a binary cuckoo search for smart home user behavior recognition. Similarly, Lu et al. utilized deep learning techniques to model user water consumption behavior, achieving accurate differentiation between multiple types of water usage events.

B. Smart Home Marketing Strategy Research

In the realm of marketing strategies, researchers both domestically and internationally have attempted to integrate user behavior data with corporate marketing decisions. Kong proposed a big data-based framework for enterprise digital precision marketing, facilitating customer segmentation and personalized promotion through statistical analysis of consumer behavior. Wang et al. developed a deep learning-based method to extract user experience elements from User-Generated Content (UGC), providing valuable insights for enterprises to improve their products and services. However, existing studies still exhibit shortcomings, such as insufficient granularity in behavior recognition and a lack of personalization in marketing strategies, failing to establish a systematic data-driven marketing framework.

In summary, although prior research has made preliminary progress in user behavior recognition and marketing strategy optimization, there remains considerable room for improvement in areas such as model accuracy, depth of behavioral insight, and dynamic strategy adjustment. The Transformer-LSTM hybrid model proposed in this paper aims

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to enhance the accuracy of user behavior recognition and the targeting of marketing strategies by integrating global features with local temporal dynamics.

III. Methodology Design

The proposed methodological framework in this study comprises three core components: data preprocessing, construction of the Transformer-LSTM hybrid model, and marketing strategy generation.

A. Data Preprocessing

The initial phase involves cleaning the raw user behavior data by removing noise and outliers, followed by addressing missing values through interpolation or mean imputation. Subsequently, key features are extracted from operational logs—such as daily usage frequency, single heating duration, and temporal usage preferences—to construct high-dimensional feature vectors. To enhance model performance, Z-Score normalization is applied to standardize the features, with the calculation formula as follows:

$$x^{\hat{a}} = (x - \mu) / \sigma$$

where μ is the mean of all sample data, and σ is the standard deviation of all sample data.

B. Transformer-LSTM Hybrid Model

To effectively capture both long-term dependencies and local temporal dynamics in user behavior sequences, a hybrid model integrating Transformer and LSTM architectures is designed.

Transformer Module: The multi-head self-attention mechanism is employed to capture global dependencies within user behavior sequences. By calculating association weights between different time steps, the model can identify cross-temporal behavioral patterns, such as concentrated water usage during weekends. The encoder layers, composed of multiple self-attention sub-layers and feed-forward neural networks, enable parallel computation and efficient training without relying on recurrent structures.

LSTM Module: To address the temporal characteristics of user behavior data, LSTM's gating mechanisms—input gate, forget gate, and output gate—are utilized to model local dynamics. The incorporation of Zoneout and Dropout techniques enhances the model's generalization capability for non-stationary sequences, enabling effective identification of critical events such as early signs of equipment failure.

Hybrid Mechanism: The global behavioral features extracted by the Transformer and the local temporal dynamics captured by the LSTM are fused through a fully connected layer to produce the final user behavior classification results. This hybrid approach retains the parallel processing advantages of the self-attention mechanism while improving the model's analytical precision for complex user behaviors.

C. Marketing Strategy Generation

Based on the user behavior recognition results, multi-dimensional user profiles are constructed by integrating demographic attributes such as region, age, and gender. Personalized marketing strategies are then designed for different user segments—for instance, recommending energy-efficient water heaters to users with frequent nighttime usage or suggesting high-capacity models for large households. A dynamic feedback mechanism is established to continuously refine the strategies based on market responses, thereby improving the conversion rates of marketing campaigns and enhancing user satisfaction.

IV. Results and Analysis

A. Experimental Setup

To validate the effectiveness of the proposed method, experiments were conducted using water heater user behavior datasets sourced from multiple open-source platforms. Model performance was evaluated using Accuracy, Sensitivity, and Specificity as key metrics, with comparisons made against baseline models including standard LSTM and Transformer architectures.

B. Analysis of Expected Results

The proposed Transformer-LSTM hybrid model is anticipated to achieve superior performance in user behavior recognition tasks compared to traditional methods. The expected advantages are demonstrated in the following aspects:

Behavior Recognition Accuracy: The hybrid model is projected to achieve an accuracy exceeding 95% on the test set, significantly outperforming individual LSTM or Transformer models.

Event Classification Sensitivity: The model's sensitivity for key water usage events, such as bathing and handwashing, is expected to reach over 90%, indicating its strength in identifying high-value behaviors.

Robustness Analysis: Through the incorporation of attention mechanisms and gating structures, the model demonstrates enhanced resistance to noise data and anomalous behaviors, maintaining stable recognition performance across diverse user groups.

C. Marketing Strategy Effectiveness Evaluation

The user profiles and marketing strategies generated from the recognition results are expected to significantly improve the market responsiveness efficiency of water heater enterprises. For instance, by pushing personalized product recommendations to targeted user segments, the marketing conversion rate is projected to increase by more than 15%, alongside a user satisfaction improvement of over 10%. Furthermore, the water usage behavior analysis provided by the model offers data-driven support for enterprises to optimize product functionalities and design energy-saving modes, thereby further strengthening the product's market competitiveness.

V. Conclusion and Future Work

This paper introduces a hybrid model combining Transformer and Long Short-Term Memory (LSTM) networks for user behavior analysis and event recognition specific to water heater usage. Building upon this analytical foundation, a framework for generating personalized marketing strategies

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was developed. The model effectively integrates the capacity to capture global dependencies with the ability to model local temporal dynamics, resulting in outstanding performance in both behavior recognition accuracy and operational robustness. This provides a practical and viable technical solution for smart home appliance companies seeking to optimize product features and enhance market promotion strategies.

Future research will delve into several promising directions to further advance this work. Firstly, exploring multi-modal data fusion, by incorporating data from sources such as environmental sensors or user feedback, could lead to a more holistic and nuanced user understanding. Secondly, investigating methods for real-time strategy adjustment, potentially leveraging reinforcement learning frameworks, would allow marketing tactics to dynamically adapt to evolving user behaviors and market feedback, thereby increasing their agility and effectiveness. Finally, validating and adapting the proposed framework for other types of smart home appliances represents a significant avenue for extending the generalizability and impact of the research.

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