



Deep Learning and Dempster–Shafer Theory in Hotel Recommendation Systems: A Review

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Abstract: Context-aware recommender systems have been widely investigated in both academia and industry because they can make recommendations based on a user's current context (e.g., location, time). However, most existing context-aware techniques only use contextual information at the item level when modeling users' preferences, i.e., contextual information that correlates with users' overall evaluations of items such as ratings. Few studies have attempted to detect more fine-grained contextual preferences at the level of item aspects (e.g., a hotel's \ location, \ food quality, and \service). In this study, we use contextual weighting strategies to derive users' aspect-level context-dependent preferences from user-generated textual reviews. The inferred context-dependent preferences are then combined with users' context-independent preferences that are also inferred from reviews to react their stable requirements over time.

Keywords: Context-Aware Recommender Systems, Service Recommendation, User Reviews, Contextual Review Analysis, Hotel Recommendation.

I. INTRODUCTION

In today's fast-evolving travel and hospitality industry, personalized hotel recommendations are crucial for improving customer satisfaction. Traditional recommendation systems rely on collaborative filtering or content-based techniques, but these methods may suffer from limited data and uncertainty in user preferences. This project aims to build a hotel recommendation system that integrates Deep Learning (DL) models with Dempster-Shafer (DS) theory to improve recommendation accuracy under uncertainty. The integration of Deep Learning and Dempster-Shafer theory provides a robust framework for hotel recommendations under uncertainty. This hybrid approach will offer better decision-making, enhancing user satisfaction and trust by addressing the challenges of incomplete and conflicting data.

Hotel recommendations can be challenging due to uncertain and incomplete user information. For instance, users may not always explicitly specify their preferences (e.g., location, amenities, or budget), leading to ambiguity. Traditional approaches struggle to combine multiple factors and deal with conflicting or uncertain data. To address this, the proposed system will leverage **deep learning for feature extraction** and the **Dempster-Shafer Theory** to handle uncertainty and aggregate different types of evidence for reliable recommendations.

The proposed Hotel Recommendation System using Deep Learning (DL) and Dempster-Shafer (DS) Theory holds substantial significance for both the hospitality industry and end-users, addressing key challenges in recommendation systems and enhancing user satisfaction.

Below are the core reasons that highlight its importance:





- **Enhanced Personalization for Users**

Tailored Experiences:

By leveraging deep learning models, the system can analyze user behavior, preferences, and sentiments from reviews to offer highly relevant hotel recommendations.

Dynamic Recommendations:

The system adapts to changing preferences, improving personalization as it gathers more data from user interactions.

- **Handling Uncertainty and Incomplete Information**

Addressing Ambiguity:

Users often provide incomplete or conflicting information regarding their preferences. DS theory allows the system to manage such uncertainty effectively by aggregating different types of evidence.

Reliable Recommendations:

Even when data is sparse or noisy, the DS theory ensures the recommendation engine remains reliable by combining multiple belief sources.

- **Competitive Advantage for the Hospitality Industry**

Improved Customer Satisfaction:

Accurate and relevant hotel recommendations result in better user experiences, leading to higher customer retention and loyalty.

Reduced Churn:

Offering reliable recommendations reduces the likelihood of users switching to other booking platforms due to poor suggestions.

II. LITERATURE REVIEW

Badouch et. al. states that accurate hotel recommendations play a crucial role in enhancing the overall travel experience. In recent years, recommendation systems have gained significant popularity in the tourism industry. These systems use various techniques and algorithms to analyze user preferences and provide personalized hotel recommendations. One of the emerging methods in recommendation systems is deep learning, a branch of machine learning that focuses on training neural networks with multiple layers to make accurate predictions or classifications.

Deep learning algorithms have shown great success in various domains such as image processing and natural language processing. This chapter aims to propose a hotel recommendation system that utilizes deep learning techniques for analyzing user preferences and providing personalized recommendations. The proposed hotel recommendation system will leverage user reviews and hotel descriptions to extract meaningful features and train a deep learning model. [1]

Hossen et. al. states that In the age of modern science, everything is based on online and on the internet. Internet-based shopping has become easier and more popular because of better quality, and fast logistic systems. Internet-based shopping and booking are very comfortable. People can easily





make a booking without going outside. The most effective side part of online-based work is that people can give a review. Recognizing reviews allows others to easily understand the emotions of others and obtain the rationality result of different products. [2]

Meduri et. al. states that When it comes to creating recommendations for products, recommendation systems are an extremely important factor. They are used to filter information coming from a variety of networks and to forecast the output depending on the preferences of the user. These systems have gained a significant amount of popularity, and one business that might benefit from using recommender systems is the tourism industry. The use of recommendation systems has been shown to increase both the level of happiness and overall experience that customers have in a variety of businesses, including the travel industry.

They are generating enormous amounts of income using this method, which is why the vast majority of them are turning to recommendation systems. A subfield of machine learning is called as recommendation engines, and its primary function is to usually rank individuals or items. A recommender system, in its broadest sense, is a system that predicts the ratings that a user would give to a certain item based on their previous interactions with that item. After that, the user will be presented with a rating of these different projections. In order to provide users with product recommendations that are likely to pique their interest, recommender systems make an effort to anticipate the preferences of users. In order to get the The purpose of a hotel recommendation system is to separate the user's selection of a recommended hotel or resort from their other available alternatives. [3]

Ramzan et. al. states presents an intelligent approach to handle heterogeneous and large-sized data using machine learning to generate true recommendations for the future customers. The Collaborative Filtering (CF) approach is one of the most popular techniques of the RS to generate recommendations. We have proposed an ovel CF recommendation approach in which opinion based sentiment analysis is used to achieve hotel feature matrix by polarity identification. Our approach combines lexical analysis, syntax analysis and semantic analysis to understand sentiment towards hotel features and the profiling of guest type (solo, family, couple etc).

The proposed system recommends hotels based on the hotel features and guest type as additional information for personalized recommendation. The developed system not only has the ability to handle heterogeneous data using big data Hadoop platform but it also recommend hotel class based on guest type using fuzzy rules. Different experiments are performed over the real world dataset obtained from two hotel websites. Moreover, the values of precision and recall and F-measure have been calculated and results are discussed interms of improved accuracy and response time, significantly better than the traditional approaches. [4]

Abbasi et. al. states that Recommender systems are important tools for users to identify their preferred items and for businesses to improve their products and services. In recent years, the use of online services for selection and reservation of hotels have witnessed a booming growth. Customer' reviews have replaced the word of mouth marketing, but searching hotels based on user priorities is





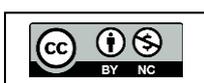
more time consuming. This study is aimed at designing a recommender system based on the explicit and implicit preferences of the customers in order to increase prediction's accuracy. In this study, we have combined sentiment analysis with the Collaborative Filtering (CF) based on deep learning for user groups in order to increase system accuracy. The proposed system uses Natural Language Processing (NLP) and supervised classification approach to analyze sentiments and extract implicit features. In order to design the recommender system, the Singular Value Decomposition (SVD) was used to improve scalability. The results show that our proposed method improves CF performance. [5]

Chih-Hao et. al. states that With a growing number of online reviews, consumers often rely on these reviews to make purchase decisions. However, little is known about managerial responses to online hotel reviews. This paper reports on a framework to integrate visual analytics and machine learning techniques to investigate whether hotel managers respond to positive and negative reviews differently and how to use a deep-learning approach to prioritize responses. In this study, forty 4- and 5-star hotels in London with 91,051 reviews and 70,397 responses were collected and analyzed. Visual analyses and machine learning were conducted. The results indicate most hotels (72.5%) showing no preference to respond to positive and negative reviews. Our proposed deep learning approach outperformed existing algorithms to prioritize responses. [6]

Dowlut, st. al. states that Precise occupancy rate (OR) forecast is essential for the sustainability of hotels in this current complex, rapidly evolving market, restricted by many factors. Failing to identify those factors and the magnitude of their influence leads to wrong perception of the hotel performance and consequently inappropriate business decisions. OR is affected by many factors, such as the availability of safe infrastructures, the pricing strategy [1], political engagement for tourism development the air access [2] among others. Predicting the occupancy of a hotel is vital for the decision-making process of revenue managers.

Managers can plan important activities, like stop sales, launch promotional offers or budgeting and even workforce management, with the ultimate goal of improving financial performance - maximise revenue and minimise costs. However, generating forecast reports with an acceptable accuracy is not a simple task and often requires specific data analytics expertise and statistical knowhow. However, generating forecast reports with an acceptable accuracy is not a simple task and often requires specific data analytics expertise and statistical knowhow. For instance, based on the traditional way of exploring historical data, the forecasting exercise carried out by the revenue managers is time consuming and tedious. Data needs to be extracted from numerous sources and the necessary analytical skills are required to come up with results. [7]

Xia st. al. conducts a comprehensive analysis of the evolution and contemporary landscape of recommendation systems, which have been extensively incorporated across a myriad of web applications. It delves into the progression of personalized recommendation methodologies tailored for on line products or services, organizing the array of recommendation techniques into four main





categories: content-based, collaborative filtering, knowledge based, and hybrid approaches, each designed to cater to specific contexts.

The document provides an in-depth review of both the historical underpinnings and the cutting-edge innovations in the domain of recommendation systems, with a special focus on implementations leveraging big data analytics. The paper also highlights the utilization of prominent datasets such as Movie Lens, Amazon Reviews, Netflix Prize, Last.fm, and Yelp in evaluating recommendation algorithms. It further outlines and explores the predominant challenges encountered in the current generation of recommendation systems, including issues related to data sparsity, scalability, and the imperative for diversified recommendation outputs. [8]

Solano-Barliza et.al. states that the tourism industry generates essential contributions to the world economy and is a valuable resource for developing nations that need to address the industry's requirements by enhancing product diversification and competitiveness in the services they provide tourism, as an economic sector, is vital because it is an essential source of income for many countries and communities, as tourists spend money on accommodation, transport, food, activities, and shopping. It can also help boost the local economy and create jobs in the tourism industry and related sectors, such as hospitality, transport, and commerce. It can also help preserve and promote the culture and heritage of a region as tourists can visit historical sites, museums, and local festivals. [9]

Henriques et. al. explores current state-of-the-art artificial intelligence (AI) methods for forecasting hotel demand. Since revenue management (RM) is crucial for business success in the hotel industry, this study aims to identify state-of-the-art effective AI-based solutions for hotel demand forecasting, including machine learning (ML), deep learning (DP), and artificial neural networks (ANNs). The study conducted an SLR using the PRISMA model and identified 20 papers indexed in Scopus and the Web of Science. It addresses the gaps in the literature on AI-based demand forecasting, highlighting the need for clarity in model specification, understanding the impact of AI on pricing accuracy and financial performance, and the challenges of available data quality and computational expertise.

The review concludes that AI technology can significantly improve forecasting accuracy and empower data-driven decisions in hotel management. Additionally, this study discusses the limitations of AI-based demand forecasting, such as the need for high-quality data. It also suggests future research directions for further enhancing AI forecasting techniques in the hospitality industry. [10].

III. PROPOSED SYSTEM

The solution integrates Deep Learning (DL) models for accurate feature extraction with Dempster-Shafer (DS) theory to handle uncertainty in user preferences. Below is an overview of the proposed solution:

- **Feature Extraction using DL:**
Utilize MLPs, CNNs, or LSTMs to extract meaningful insights from user reviews and hotel features (e.g., amenities, location). Collaborative filtering and matrix factorization will address data sparsity issues.



- **Uncertainty Management with DS Theory:**
Use DS theory to combine conflicting or incomplete data sources, assigning belief masses to different criteria (e.g., reviews, ratings).
Apply Dempster's rule to aggregate evidence from multiple aspects and produce reliable recommendations.
- **Hybrid Recommendation Model:**
Combine the outputs from the DL-based models and DS theory to generate personalized hotel recommendations.
Use multi-criteria optimization to account for various factors, such as price, user preferences, and location relevance.
- **Performance Metrics:**
Evaluate the model using precision, recall, and Mean Reciprocal Rank (MRR) to ensure high-quality recommendations.

IV. METHODOLOGY

- **Data Collection and Preprocessing:**
Gather datasets containing user reviews, ratings, hotel details, and preferences.
Preprocess the textual reviews using NLP techniques (e.g., tokenization, embedding models).
- **Feature Extraction with Deep Learning:**
Use LSTM/RNN models to capture user sentiments from reviews.
Apply CNNs for multi-aspect feature extraction (e.g., location, amenities).

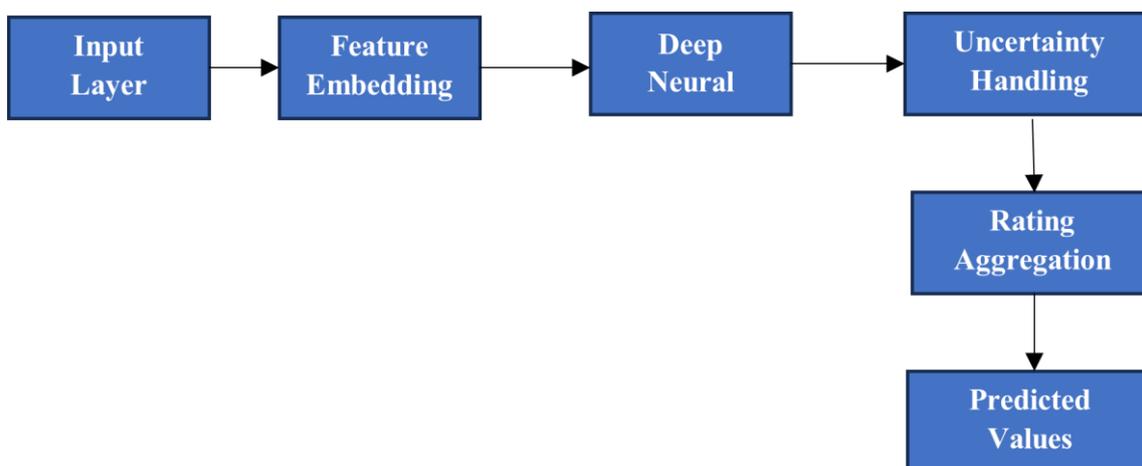


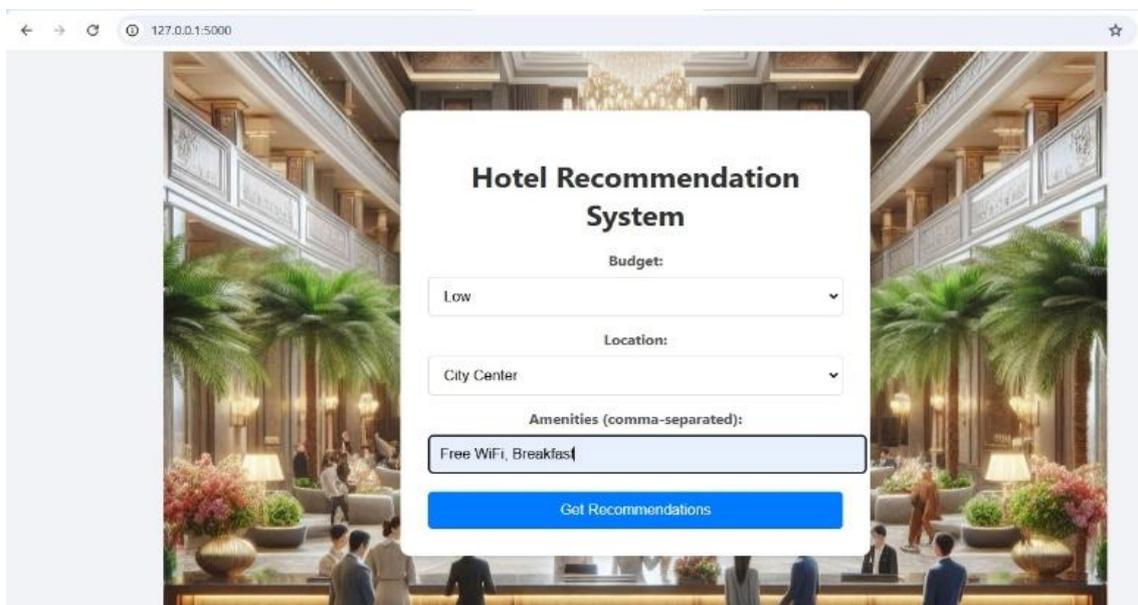
Figure 1: Architecture of the Proposed System

- **Handling Uncertainty with Dempster-Shafer Theory:**
Each piece of evidence (e.g., review sentiment, user location) is treated as a belief mass.
Use the Dempster's rule of combination to aggregate multiple evidence sources and handle conflicting information.

- **Recommendation Model:**
Train a hybrid DL model to predict user preferences and rank hotels.
The DS-based layer will integrate and weigh uncertain data to refine recommendations.
- **Testing:**
Unit and integration testing will be done to find out the performance and accuracy of the system.
- **Performance Evaluation:**
Use metrics such as precision, recall, F1-score, and Mean Reciprocal Rank (MRR) to evaluate the model's accuracy.
Compare results with traditional recommendation models to assess improvement.

V. EXPECTED OUTCOMES

1. Reccomodate hotels after processing.
2. Accuracy achieved more than previous methods.
3. A hotel recommendation system that provides accurate and personalized suggestions despite uncertain or incomplete user information.
4. Enhanced handling of conflicting reviews and preferences using DS theory.
5. Improved user satisfaction through better feature extraction with DL models.



The screenshot shows a web browser window with the URL 127.0.0.1:5000. The main content is a 'Hotel Recommendation System' form overlaid on a background image of a hotel lobby. The form includes the following fields:

- Budget:** A dropdown menu with 'Low' selected.
- Location:** A dropdown menu with 'City Center' selected.
- Amenities (comma-separated):** A text input field containing 'Free WiFi, Breakfast'.
- Get Recommendations:** A blue button at the bottom of the form.

Figure 2: Input Parameters from User

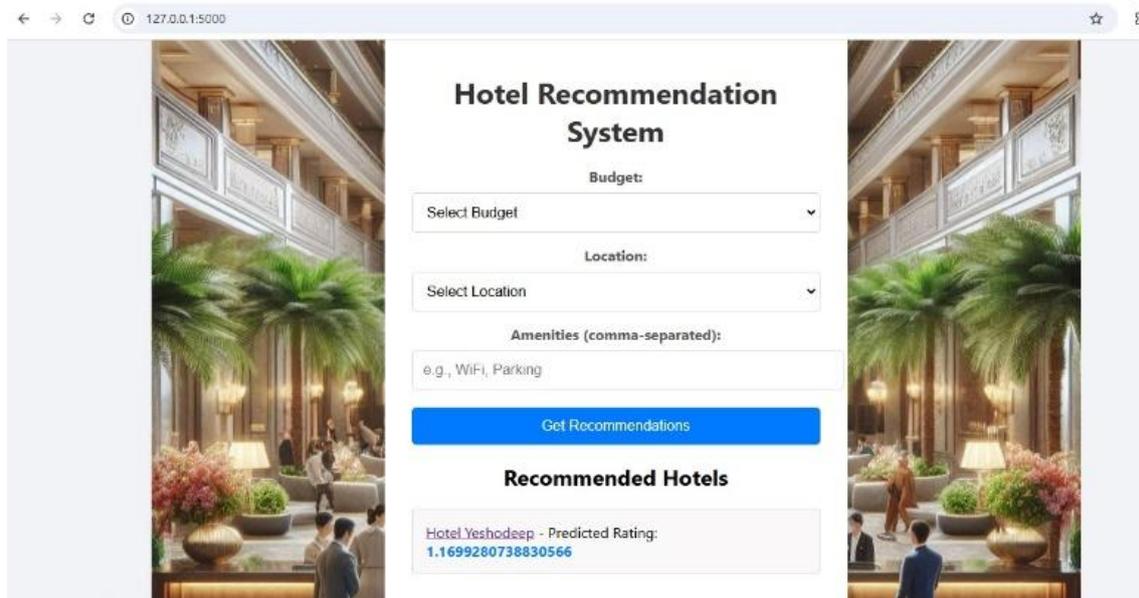


Figure 3: Prediction of Hotel with Suggestive Link

VI. LIMITATIONS

The integration of deep learning (DL) with Dempster-Shafer theory in developing a hotel recommendation system offers a robust approach to decision-making under uncertainty. Deep learning techniques enable the extraction of meaningful patterns and preferences from complex, large-scale datasets, while Dempster-Shafer theory provides a mathematical framework for combining evidence from multiple sources and handling ambiguity in user preferences.

This combined methodology ensures higher accuracy and personalization in recommendations, enhancing user satisfaction by aligning suggestions with individual needs. Moreover, the fusion of these technologies improves the system's adaptability to dynamic user behavior and varying contextual factors. Future advancements can focus on refining data preprocessing, incorporating additional contextual features, and optimizing the model's computational efficiency.

In conclusion, the synergy between DL and Dempster-Shafer theory sets a strong foundation for intelligent, user-centric recommendation systems in the hospitality industry, paving the way for further innovations in the field.

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