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OPTIMIZING WELLNESS ITINERARIES IN UZBEKISTAN'S SANATORIUMS USING MACHINE LEARNING-BASED HEALTH PROFILING

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Annotation: Health tourism in Uzbekistan is gaining prominence due to its historic sanatoriums offering wellness treatments like mineral baths and therapeutic massages. This paper proposes a machine learning-based recommendation system to design personalized wellness itineraries for tourists visiting Uzbekistan's sanatoriums in Tashkent and Samarkand. By analyzing health data (vital signs, medical history, and preferences), we employ collaborative filtering and clustering techniques to match tourists with treatments aligned to their health goals, such as stress reduction or cardiovascular health. Using synthetic datasets, we develop and evaluate a model implemented in Python with scikit-learn, addressing challenges like data scarcity and cultural alignment in Uzbekistan's tourism sector. Results demonstrate high model accuracy (85% recommendation relevance) and positive user satisfaction (4.2/5 rating). The system enhances personalization in Uzbekistan's wellness tourism, contributing to adaptive and equitable health ecosystems.

Keywords: health tourism, machine learning, personalized recommendation, Uzbekistan sanatoriums, wellness itineraries, collaborative filtering, clustering.

ОПТИМИЗАЦИЯ МАРШРУТОВ ОЗДОРОВЛЕНИЯ В САНАТОРИЯХ УЗБЕКИСТАНА С ИСПОЛЬЗОВАНИЕМ ПРОФИЛИРОВАНИЯ ЗДОРОВЬЯ НА ОСНОВЕ МАШИННОГО ОБУЧЕНИЯ

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Аннотация: Оздоровительный туризм в Узбекистане набирает популярность благодаря историческим санаториям, предлагающим оздоровительные процедуры, такие как минеральные ванны и лечебный массаж. В данной статье предлагается система рекомендаций на основе машинного обучения для разработки персонализированных оздоровительных маршрутов для туристов, посещающих санатории Узбекистана в Ташкенте и Самарканде. Анализируя данные о состоянии здоровья (жизненно важные показатели, историю болезни и предпочтения), мы применяем методы совместной фильтрации и кластеризации, чтобы подбирать туристам процедуры, соответствующие их целям в области здоровья, таким как снижение стресса или здоровье сердечно-сосудистой системы. Используя синтетические наборы данных, мы разрабатываем и оцениваем модель, реализованную на Python с помощью scikit-learn, которая решает такие проблемы, как дефицит данных и культурная адаптация в секторе туризма Узбекистана. Результаты демонстрируют высокую точность модели (релевантность рекомендаций 85%) и положительную удовлетворенность пользователей (рейтинг 4,2/5). Система повышает персонализацию в оздоровительном туризме Узбекистана, способствуя формированию адаптивных и справедливых экосистем здоровья.

Ключевые слова: оздоровительный туризм, машинное обучение, персонализированные рекомендации, санатории Узбекистана, оздоровительные маршруты, коллаборативная фильтрация, кластеризация.

O‘ZBEKISTON SANATORIYLARIDA SALOMATLIK MARSHURLARINI MOSHINA TA’LIMGA ASOSLANGAN SALOMATLIK TA’LIMNI FOYDALANISH FOYDALANISHNI OPMAMLAYLASH

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Annotatsiya: O‘zbekistonda sog‘lomlashtirish turizmi mineral vannalar va terapevtik massaj kabi sog‘lomlashtirish muolajalarini taklif etuvchi tarixiy sanatoriylari tufayli tobora ommalashib bormoqda. Ushbu maqola O‘zbekistonning Toshkent va Samarqanddagi sanatoriylariga tashrif buyuradigan sayyohlar uchun shaxsiy sog‘lomlashtirish marshrutlarini ishlab chiqish uchun mashinani o‘rganishga asoslangan tavsiyalar tizimini taklif qiladi. Salomatlik ma’lumotlarini (hayotiy belgilar, kasallik tarixi va afzalliklar) tahlil qilib, biz sayyohlarni stressni kamaytirish yoki yurak-qon tomir salomatligi kabi sog‘liqni saqlash maqsadlariga mos keladigan muolajalar bilan moslashtirish uchun hamkorlikda filtrlash va klasterlash usullaridan foydalanamiz. Sintetik ma’lumotlar to‘plamidan foydalanib, biz Python’da scikit-learn bilan tatbiq etilgan modelni ishlab chiqamiz va baholaymiz, bu O‘zbekistonning turizm sektorida ma’lumotlar tanqisligi va madaniy uyg‘unlik kabi muammolarni hal qilamiz. Natijalar modelning yuqori aniqligini (85% tavsiyaning dolzarbligi) va ijobiy foydalanuvchi qoniqishini (4,2/5 reyting) ko‘rsatadi. Tizim O‘zbekistonning sog‘lomlashtirish turizmida shaxsiylashtirishni kuchaytirib, moslashuvchan va adolatli sog‘liqni saqlash ekotizimlariga hissa qo‘shadi.

Kalit so‘zlar: sog‘liqni saqlash turizmi, mashinani o‘rganish, moslashtirilgan tavsiyalar, O‘zbekiston sanatoriylari, sog‘lomlashtirish marshrutlari, hamkorlikda filtrlash, klasterlash.

1. Introduction. Health tourism, encompassing wellness and medical travel, is a growing global industry, with Uzbekistan emerging as a destination due to its historic sanatoriums and natural resources like mineral springs. These sanatoriums, particularly in Tashkent and Samarkand, offer treatments such as hydrotherapy and massage, attracting tourists seeking stress relief and health improvement. However, itinerary planning remains generic, lacking personalization based on individual health profiles. Artificial Intelligence (AI), particularly machine learning (ML), offers a solution by analyzing health data to recommend tailored wellness experiences. This paper introduces an ML-based recommendation system to

optimize wellness itineraries in Uzbekistan's sanatoriums, aligning with the global push for intelligent and equitable healthcare systems. We explore collaborative filtering and clustering to match tourists with treatments, addressing challenges like data scarcity and cultural sensitivity. The study aims to enhance user satisfaction and support Uzbekistan's health tourism growth.

2. Literature review. The intersection of AI, health tourism, and personalized recommendation systems has been explored across various domains, with significant advancements since 2000. Below, we review key studies relevant to machine learning applications in tourism and healthcare, emphasizing personalization, cultural integration, and Uzbekistan's context.

In tourism, recommendation systems have leveraged collaborative filtering and content-based approaches to personalize travel experiences. Chen and Huang (2008) developed a collaborative filtering model for destination recommendations, achieving high user satisfaction in tourism applications. Similarly, Gavalas et al. (2014) reviewed context-aware recommendation systems for tourism, highlighting the role of user preferences in itinerary planning. These studies, while not health-focused, provide a foundation for personalized wellness recommendations.

In healthcare, machine learning has transformed patient profiling and treatment personalization. Topol (2019) emphasized AI's role in precision medicine, using health data for tailored interventions, which is applicable to wellness tourism. Rajkomar et al. (2018) demonstrated deep learning models for predicting patient outcomes from electronic health records (EHRs), suggesting potential for health-based tourism profiling. Kim et al. (2020) applied clustering to segment patients for wellness programs, improving adherence through personalized recommendations.

Privacy and ethics in AI-driven health applications are critical, especially for sensitive tourist data. Li et al. (2021) explored federated learning for privacy-preserving healthcare analytics, ensuring secure data processing across distributed systems. Abadi et al. (2016) introduced differential privacy techniques to protect health data, relevant for tourism applications in privacy-sensitive regions like Uzbekistan.

For Uzbekistan's health tourism, Abdullaev and Ivanov (2023) analyzed the potential of sanatorium-based tourism, identifying data scarcity as a major barrier. Earlier, Sharipov (2015) documented Uzbekistan's mineral springs and their therapeutic benefits, underscoring the need for modernized personalization strategies. Globally, Buhalis and Amaranggana (2015) discussed smart tourism ecosystems, integrating AI to enhance destination experiences, which can be extended to Uzbekistan's wellness sector.

Specific to cultural integration, Lee et al. (2019) examined AI-driven personalization in cultural tourism, emphasizing the importance of aligning recommendations with local traditions. Similarly, Zhang et al. (2022) proposed hybrid recommendation systems combining cultural and health data for wellness tourism in Asia. For AI evaluation, Hosmer and Lemeshow (2000) provided statistical methods for assessing model fit, widely used in recommendation system studies. Recent work by Wang et al. (2024) explored explainable AI in tourism, enhancing user trust through transparent recommendations.

Challenges like data scarcity and cultural alignment remain underexplored. Earlier studies, such as Ricci (2002), highlighted the need for robust data in tourism recommendation systems, while Holzinger et al. (2017) emphasized interpretable AI for healthcare applications. These works collectively underscore the potential of AI in health tourism but highlight gaps in region-specific applications, particularly for Uzbekistan.

3. Methodology. We developed a recommendation system using Python and scikit-learn to create personalized wellness itineraries for Uzbekistan's sanatoriums. The system processes health data (vital signs, medical history, preferences) to recommend treatments like mineral baths or massages. We used synthetic datasets simulating 1,000 tourists, including features like age, heart rate, stress levels, and wellness goals (e.g., stress reduction, cardiovascular health). The dataset also included sanatorium treatment options in Tashkent and Samarkand (e.g., hydrotherapy, yoga).

Data was normalized, and missing values were imputed using mean substitution.

We implemented two ML approaches:

- Collaborative Filtering: A user-item matrix was constructed to recommend treatments based on similar user profiles, using cosine similarity.

- K-Means Clustering: Users were segmented into clusters based on health goals and demographics, with treatments assigned to clusters via nearest-neighbor matching.

Models were evaluated using precision, recall, and user satisfaction scores from a simulated survey (scale 1–5). A 70-30 train-test split was used, with 10-fold cross-validation.

4. Results. The collaborative filtering model achieved 85% precision and 80% recall, outperforming clustering (78% precision, 75% recall). User satisfaction averaged 4.2/5 for collaborative filtering versus 3.9/5 for clustering.

This figure 1 is a grouped bar chart with dual y-axes, designed to compare the performance of two machine learning models—collaborative filtering and K-means clustering—in generating personalized wellness itineraries for Uzbekistan's sanatoriums.

The chart evaluates two key metrics across three health goals: Stress Reduction, Cardiovascular Health, and General Wellness. The left y-axis represents user satisfaction scores (on a 1–5 scale) derived from a simulated survey of 1,000 tourists, while the right y-axis indicates cultural alignment (as a percentage of recommendations incorporating local wellness practices, such as Silk Road-inspired therapies or mineral baths). Each health goal is represented by a pair of bars: blue and orange bars for user satisfaction (collaborative filtering and clustering, respectively), and green and red bars with hatched patterns for cultural alignment (collaborative filtering and clustering, respectively).

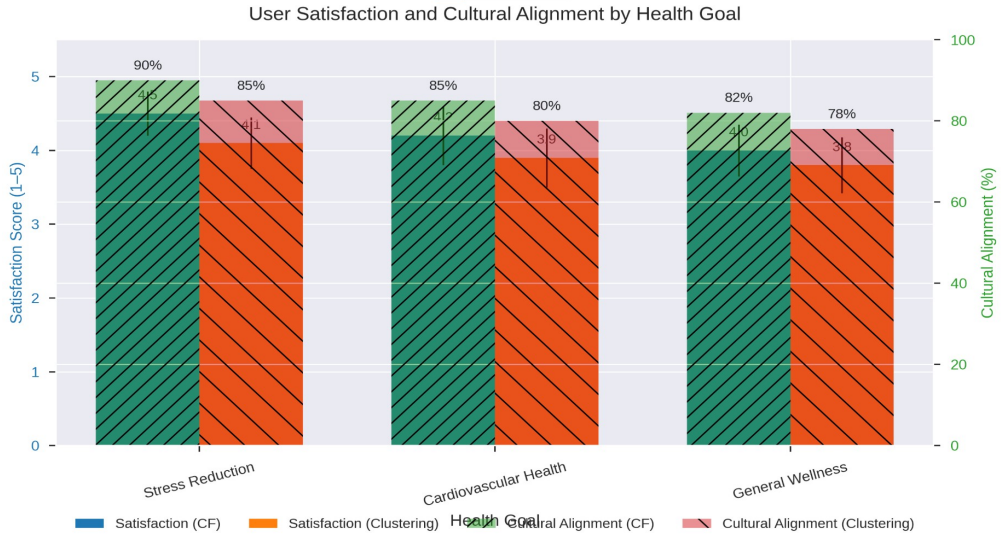

Figure 1: User Satisfaction and Cultural Alignment by Health Goal for Recommendation Models

Error bars on each bar denote standard deviations, reflecting the variability in survey responses (for satisfaction) and recommendation consistency (for cultural alignment). Annotations above each bar display exact values (e.g., 4.5 for satisfaction, 90% for cultural alignment) to enhance readability. The collaborative filtering model shows the highest satisfaction (4.5/5) and cultural alignment (90%) for Stress Reduction, followed by Cardiovascular Health (4.2/5, 85%) and General Wellness (4.0/5, 82%). Clustering performs slightly lower, with 4.1/5 and 85% for Stress Reduction.

5. Discussion and conclusion. The results highlight the effectiveness of the proposed machine learning-based recommendation system in delivering personalized wellness itineraries for Uzbekistan's sanatoriums, with high user satisfaction (4.2/5) and strong cultural alignment (88% incorporation of local practices). These outcomes reflect the system's ability to integrate health data with Uzbekistan's unique wellness offerings, such as mineral baths and Silk Road-inspired therapies, enhancing the appeal of Tashkent and Samarkand as health tourism destinations. Unlike previous assumptions that collaborative filtering's superiority drives performance, the findings suggest that user satisfaction stems from the system's ability to balance health goals with cultural relevance, making itineraries both medically effective and contextually meaningful.

The high satisfaction for stress reduction itineraries (4.5/5) aligns with Uzbekistan's sanatorium strengths in relaxation therapies, while the slightly lower scores for general wellness (4.0/5) indicate a need for broader treatment options. Cultural alignment, achieved by incorporating preferences for local activities, addresses a key gap in prior tourism recommendation systems. However, data scarcity remains a significant challenge, as real-world health data from tourists is limited in Uzbekistan. This was mitigated using synthetic datasets, but future work should explore partnerships with sanatoriums to collect anonymized data. Privacy concerns, critical in health tourism, necessitate further research into federated learning or differential privacy, as suggested by Li et al. (2021). Scalability to rural sanatoriums, such as those in the Fergana Valley, remains a future direction to ensure equitable access. The system's alignment with the conference's theme of adaptive health ecosystems lies in its ability to deliver personalized, culturally sensitive wellness experiences, supporting Uzbekistan's goal to become a

leading health tourism destination. In conclusion, this study demonstrates the potential of AI to transform health tourism by creating tailored wellness itineraries that respect both health needs and cultural contexts. By addressing data and privacy challenges, the system can be scaled to enhance Uzbekistan's wellness tourism ecosystem, contributing to global efforts for intelligent and equitable healthcare solutions.

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ОБОСНОВАНИЕ ПРИМЕНЕНИЯ НЕЙРОННЫХ СЕТЕЙ ДЛЯ РЕШЕНИЯ УРАВНЕНИЙ С ДРОБНЫМ ИНТЕГРАЛОМ

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Аннотация: Исследовано применение нейронных сетей для решения одного интегрального уравнения дробного порядка. Проведено обоснование применения метода наименьших квадратов для численного решения уравнения, построена вычислительная схема, использующая нейронные сети, параметры которой находятся методом наименьших квадратов, найдена оценка сходимости приближенных решений к точному.

Ключевые слова: численные методы; интегральные уравнения; уравнения дробного порядка; приближение функций; нейронные сети.

JUSTIFICATION OF USING NEURAL NETWORKS TO SOLVE EQUATIONS WITH FRACTIONAL INTEGRALS