FAIR AND TRANSPARENT ALGORITHMIC SOLUTIONS IN E-COMMERCE AND GIG ECONOMIES

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by

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THESIS CERTIFICATE

This is to certify that the thesis titled, **"Fair and Transparent Algorithmic Solutions in E-commerce and Gig Economies"**, submitted by **ANJALI GUPTA**, to the Indian Institute of Technology, Delhi, for the award of the degree of **Doctor of Philosophy**, is a bona fide record of the research work done by her under my supervision. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

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ABSTRACT

Digital platforms, including e-commerce, social commerce, and gig-based services, are reshaping the global economy, offering unprecedented opportunities while raising critical challenges related to fairness, transparency, and personalization. In gig economy platforms, particularly food delivery services, workers face income instability and opaque task allocation mechanisms, leading to economic disparities. Social commerce platforms empower local sellers and re-sellers but lack fair exposure mechanisms, often concentrating earnings among a small subset of users. Meanwhile, e-commerce platforms struggle with accurately identifying user personas, which is crucial for delivering personalized recommendations while ensuring diverse and equitable representation.

This thesis advances fairness and transparency in digital marketplaces by developing data-driven, algorithmic solutions across three domains: (1) fair income distribution for gig workers in food delivery platforms, (2) fair earning allocation in social commerce, and (3) persona identification in e-commerce. For gig workers, this research formulates fair income distribution as a constrained optimization problem, proposing novel allocation algorithms that balance wage equity with platform efficiency. In social commerce, a fair division model is introduced to ensure equitable exposure and revenue opportunities for re-sellers, leveraging fairness concepts such as Nash social welfare and envy-freeness. In e-commerce, this thesis presents a persona identification framework using Graph Neural Networks (GNNs), modeling user behaviors and interactions in a heterogeneous graph structure. All methodologies developed in this thesis have been rigorously tested on real-world datasets and formulated in collaboration with industry partners, ensuring practical relevance and applicability. By integrating algorithmic fairness, machine learning, and real-world constraints, this research contributes to building more equitable, transparent, and user-centric digital marketplaces.

The findings of this thesis provide a foundation for future research on fairness in digital economies, setting the stage for enhanced transparency, equitable opportunity distribution, and improved personalization in evolving online platforms.

सारांश

डिजिटल प्लेटफ़ॉर्म, जिनमें ई-कॉमर्स, सोशल कॉमर्स और गिग-आधारित सेवाएँ शामिल हैं, वैश्विक अर्थव्यवस्था को पुनर्परिभाषित कर रहे हैं। ये अभूतपूर्व अवसर प्रदान करते हैं, साथ ही निष्पक्षता, पारदर्शिता और वैयक्तिकरण से जुड़ी महत्वपूर्ण चुनौतियाँ भी उत्पन्न करते हैं। गिग अर्थव्यवस्था के प्लेटफ़ॉर्म, विशेष रूप से फूड डिलीवरी सेवाओं में, श्रमिकों को आय में अस्थिरता और अपारदर्शी कार्य-आवंटन तंत्र का सामना करना पड़ता है, जिससे आर्थिक असमानताएँ बढ़ती हैं। सोशल कॉमर्स प्लेटफ़ॉर्म स्थानीय विक्रेताओं और री-सेलर्स को सशक्त बनाते हैं, परंतु निष्पक्ष एक्सपोज़र तंत्र की कमी के कारण आय अक्सर सीमित उपयोगकर्ताओं के एक छोटे समूह में केंद्रित हो जाती है। वहीं, ई-कॉमर्स प्लेटफ़ॉर्म उपयोगकर्ता व्यक्तित्व (पर्सोना) की सटीक पहचान करने में संघर्ष करते हैं, जो विविध और न्यायसंगत प्रतिनिधित्व सुनिश्चित करते हुए व्यक्तिगत अनुशंसाएँ प्रदान करने के लिए अत्यंत महत्वपूर्ण है।

यह शोधप्रबंध डिजिटल बाज़ारों में निष्पक्षता और पारदर्शिता को आगे बढ़ाने हेतु तीन प्रमुख क्षेत्रों में डेटा-आधारित, एल्गोरिथ्मिक समाधान प्रस्तुत करता है: (1) फूड डिलीवरी प्लेटफ़ॉर्म पर गिग श्रमिकों के लिए निष्पक्ष आय वितरण, (2) सोशल कॉमर्स में निष्पक्ष आय आवंटन, और (3) ई-कॉमर्स में पर्सोना पहचान। गिग श्रमिकों के संदर्भ में, यह शोध निष्पक्ष आय वितरण को एक बाधित अनुकूलन (कंस्ट्रेन्ड ऑप्टिमाइजेशन) समस्या के रूप में प्रस्तुत करता है और ऐसे नवीन आवंटन एल्गोरिथ्म प्रस्तावित करता है जो वेतन समानता और प्लेटफ़ॉर्म दक्षता के बीच संतुलन स्थापित करते हैं। सोशल कॉमर्स में, री-सेलर्स के लिए न्यायसंगत एक्सपोज़र और राजस्व अवसर सुनिश्चित करने हेतु एक निष्पक्ष विभाजन मॉडल प्रस्तुत किया गया है, जिसमें नैश सोशल वेलफेयर और ईर्ष्या-रहितता (एन्वी-फ्रीनेस) जैसे निष्पक्षता सिद्धांतों का उपयोग किया गया है। ई-कॉमर्स में, यह शोधप्रबंध ग्राफ न्यूरल नेटवर्क (जीएनएनएस) के माध्यम से एक पर्सोना पहचान ढाँचा प्रस्तुत करता है, जो विषम ग्राफ संरचना में उपयोगकर्ता व्यवहार और अंतःक्रियाओं का मॉडलिंग करता है। इस शोध में विकसित सभी कार्यप्रणालियों का वास्तविक-दुनिया के डेटा-सेट्स पर कठोर परीक्षण किया गया है तथा इन्हें उद्योग सहयोगियों के साथ मिलकर तैयार किया गया है, जिससे उनकी व्यावहारिक प्रासंगिकता और उपयोगिता सुनिश्चित होती है। एल्गोरिथ्मिक निष्पक्षता, मशीन लर्निंग और वास्तविक-दुनिया की बाधाओं को एकीकृत करते हुए, यह शोध अधिक न्यायसंगत, पारदर्शी और उपयोगकर्ता-केंद्रित डिजिटल बाज़ारों के निर्माण में योगदान देता है।

इस शोधप्रबंध के निष्कर्ष डिजिटल अर्थव्यवस्थाओं में निष्पक्षता पर भविष्य के अनुसंधान के लिए एक ठोस आधार प्रदान करते हैं, जो विकसित होते ऑनलाइन प्लेटफ़ॉर्म में अधिक पारदर्शिता, समान अवसर वितरण और बेहतर वैयक्तिकरण की दिशा में मार्ग प्रशस्त करते हैं।

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