Development of Eleven Types of Cartesian Product Operations in Complex Exponential Intuitionistic Fuzzy Matrices

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Abstract: This paper introduces a family of eleven Cartesian product operators ($\times_1$–$\times_{11}$) for complex exponential intuitionistic fuzzy sets. The proposed approach represents membership and non-membership degrees using complex exponential forms to capture both magnitude and phase information. The operators are constructed using different aggregation mechanisms such as algebraic product, sum, bounded operations, and averaging. Fundamental properties including commutativity and boundedness are discussed. The framework generalizes existing intuitionistic fuzzy operations and provides greater flexibility in handling uncertainty. The proposed model is suitable for applications in decision-making and pattern analysis involving complex-valued information. The author developed the concept of complex exponential operational laws for intuitionistic fuzzy sets and defined the eleven Cartesian product operators ($\times_1$–$\times_{11}$). The author formulated the mathematical models, analysed their algebraic properties, and established relationships among the operators. The author also interpreted the theoretical results and prepared the manuscript.

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