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A Study of Fuzzy Set Extensions in Real and Complex Planes

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ABSTRACT

Fuzzy set extensions in real and complex planes represent a significant advancement in the mathematical modeling of uncertainty, vagueness, and imprecision. Traditional fuzzy sets, introduced by Lotfi Zadeh, define membership functions mapping elements of a universe to the interval [0,1], indicating degrees of belonging. Extending this concept to the real plane allows fuzzy sets to handle multidimensional data, where each point in $\mathbb{R}^2$ or $\mathbb{R}^n$ has a fuzzy membership value, facilitating applications in image processing, decision-making, and pattern recognition. Similarly, fuzzy set extensions in the complex plane provide a framework for representing uncertainty in systems with oscillatory or phase-dependent behavior, such as electrical engineering, signal processing, and quantum mechanics. In the complex domain, membership functions can incorporate both magnitude and phase information, enabling richer representations of ambiguity and partial truth. Mathematical operations, including union, intersection, and complement, can be generalized to these planes, often requiring novel formulations like α-cuts, fuzzy arithmetic, and complex-valued membership functions. These extensions enhance the ability of fuzzy systems to model real-world phenomena where uncertainty is inherently multidimensional or phase-dependent, offering more flexible, accurate, and interpretable tools for analysis and computational intelligence in diverse scientific and engineering applications.

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