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Causal perturbative Quantum Field Theory in the Epstein Glaser approach: Graphs and Hopf algebras

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Abstract

The thesis aims at investigating causal perturbative quantum field theory in the Epstein Glaser approach and, in particular, its formulation in the language of Hopf algebras. Five different Hopf algebras are encountered, each one associated with a special combination of physical concepts such as graded total symmetry, pseudo-unitarity, causality, and renormalization. Thereby the question about possible analogs of Kreimer's Hopf algebra of renormalization gets a positiv answer. The Hopf algebraic structures are imposed on the operator-valued distributions which represent the perturbative expansion of the S-matrix, implemented by appropriate graph type indices (forming Hopf algebras of vertex tuples and graphs). Translation invariance ensures the algebras to be analytically well-defined and the assumption of graded total symmetry allows to formulate bialgebras. The Hopf-algebraic results are given embedded in the presentation of the physical framework, starting with free fields (which can as well be ghosts), their quantization, and resulting propagators, proceeding with the infrared regularized perturbation ansatz, the introduction of graphs, etc., and ending at two versions (going back to Fredenhagen and Scharf) which realize the recursive implementation of causality (e.g., given by a modified distribution splitting for Scharf's version). Besides, following the BPHZ approach in a maximal regularization, the ultraviolet divergences occuring in Feynman's representation are mathematically reasoned. The above mentioned concepts are the only ones which will be (Hopf-) algebraically formalized, i.e., the presented renormalization procedure does not involve physical criteria to fix the renormalization ambiguity.

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