This article investigates general relations between tree and loop amplitudes in gauge theories. One of the main motivations is to find a new calculatory method in loop amplitudes which is to be an alternative to the standard unitary-based methods [1, 2]. Another motivation, although implicit in the article, would be a recently proposed iterative relation, in loop order, among maximally helicity violating (MHV) amplitudes of planer $\mathcal{N} = 4$ super Yang-Mills theory [3, 4].

A typical relation between tree and one-loop amplitudes can be given by Feynman's tree theorem, with its particular form recently obtained in [5]. In this paper generalization of this relation to higher-loop orders is considered by use of the physical principles of causality and locality. For planar gauge theories an interesting computational method is obtained, which simplifies the multi-loop expressions as integrands over on-shell measures. Later this result is developed further in [6] which derives a general recursive relation among loop integrands in planar $\mathcal{N} = 4$ super Yang-Mills theory.

For non-planar gauge theories, similar simplification is attempted in the article but the situation does not seem satisfactory. Yet with supersymmetry, the author argues that some simplifications do occur. For a non-planar analysis of related recursive relations, see also [7].

References

[1] Z. Bern, L. J. Dixon, D. C. Dunbar and D. A. Kosower, Nucl. Phys. B **425**, 217 (1994) [hep-ph/9403226].

[2] Z. Bern, L. J. Dixon, D. C. Dunbar and D. A. Kosower, Nucl. Phys. B **435**, 59 (1995) [hep-ph/9409265].

[3] C. Anastasiou, Z. Bern, L. J. Dixon and D. A. Kosower, Phys. Rev. Lett. **91**, 251602 (2003) [arXiv:hep-th/0309040].

[4] Z. Bern, L. J. Dixon, V. A. Smirnov, Phys. Rev. **D72**, 085001 (2005). [hep-th/0505205].

[5] S. Catani, T. Gleisberg, F. Krauss, G. Rodrigo and J. -C. Winter, JHEP **0809**, 065 (2008) [arXiv:0804.3170 [hep-ph]].

[6] N. Arkani-Hamed, J. L. Bourjaily, F. Cachazo, S. Caron-Huot and J. Trnka, JHEP **1101**, 041 (2011) [arXiv:1008.2958 [hep-th]].

[7] R. H. Boels, JHEP **1011**, 113 (2010) [arXiv:1008.3101 [hep-th]].