Statistical physics of balance theory

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Triadic relationships are accepted to play a key role in the dynamics of social and political networks. Building on insights gleaned from balance theory in social network studies and from Boltzmann-Gibbs statistical physics, we propose a model to quantitatively capture the dynamics of the different types of triadic relationships in a network. Central to our model are the triads' incidence rates and the idea that those can be modeled by assigning a specific triadic energy to each type of triadic relation. We emphasize the role of the degeneracy of the different triads and how it impacts the degree of frustration in the political network. In order to account for a persistent form of disorder in the formation of the triadic relationships, we introduce the systemic variable temperature. In order to learn about the dynamics and motives, we propose a generic Hamiltonian with three terms to model the triadic energies. One term is connected with a three-body interaction that captures balance theory. The other terms take into account the impact of heterogeneity and of negative edges in the triads. The validity of our model is tested on three datasets including the time series of triadic relationships for the standings between of alliances in a massively multiplayer online game (MMOG). We also analyze real-world data for the relations between countries during the Cold War era. We find emerging properties in the triadic relationships in a political network, for example reflecting itself in the consistency of the extracted parameters from comparing the model Hamiltonian to the data. A natural extension of classical Social Balance Theory is the introduction of “neutral interactions" between the agents. This extension could, for example, be used to accommodate the changes in the inter-country relationships from "neutral" to "hostile" or "friendly".