Chapter 12

From Microscopic Rules to Emergent Cooperativity in Large-Scale Patterns

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Abstract. Assembled large-scale systems of nano-particles or molecules can be represented by graphs (network structures), in which nodes and links have specified physical attributes. We consider two classes of complex spin-networks, in which spins with two degrees of freedom are attached to nodes of the network. We first demonstrate how different network geometries emerge when the microassembly rules and constraints are varied. We then study the dynamic response when these large-scale structures are driven by the magnetic field and show how the hysteresis curves and memory properties are affected by structural complexity of the underlying network.

1. Introduction

Self-assembly processes, in which structurally complex large-scale systems of nano-particles [1,2] or molecules emerge, offer challenging prospectives both for applications and condensed matter physics. The key feature of the self-assembled systems is their structural and functional complexity. Even when the physical, chemical or biological properties of the integrating elements (*i.e.*, molecules, nano-particles) are known in detail, the assembled large-scale structure often has new *emergent* properties that are not present at the level of individual elements. In this way, the self-assembled systems represent true *complex systems*, owing to the nonlinearity of the self-assembly processes.

Considering several studied examples, one can find that the self-assembly often utilizes a distinct physical principle which makes the process possible. So far known processing procedures can be roughly divided into following categories:

– *Synthesis* (*e.g.*, evaporation methods), in which nano-crystals [3] or nano-crystal clusters [4] and nano-tubes [5,6] are obtained. In the classical case of the carbon nano-tubes, for instance, the assembly process can be viewed as adding two carbon atoms per evolution step and utilizing the underlying *line symmetry* of the interaction [7].

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