Hypernetworks in complex multilevel systems

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Networks have been very important in understanding the dynamics of complex systems. Surprisingly the focus of network science remains on binary relations between pairs of entities and little attention is paid to relations between $n > 2$ things. For example, the dynamics of the structure < mother, father, daughter > cannot be adequately described by the edges < mother, father >, < mother, daughter > and < father, daughter >. Generalisations to n-ary relations have included hypergraphs in which edges are sets with any number of elements, and simplicial complexes which generalise oriented edges to simplices. Thus one-dimensional edges < a, b > in networks are generalised to p-dimensional simplices in simplicial complexes. Hypernetworks offer a further generalisation by making explicit the relation that binds the n vertices together in relational simplices, such as <mother, father, daughter; R-family>. This allows for the possibility that the vertices can be combined in different ways to form different emergent entities. For example, the letters { a, p, t } can be combined in different way to for the relational simplices < a, p, t; R-pat > =/= < a, p, t; R-tap >. Relational simplices provide an algebraic way of representing the parts and wholes in multilevel systems. By moving to higher dimensions, hypernetworks have a richer connectivity structure than networks. Two simplices are q-near when they share a q-dimensional face. Simplices are q-connected by chains of pairwise q-near simplices. As with networks, the connectivity structure underlies system dynamics. This talk will be developed through examples in the planning, design, and management of complex socio-technical systems.