Abstract:

Beyond simplicial complexes: hypernetworks for systems of systems of systems

An expert report1 on complex systems published recently by the European Commission "identified the dynamics of multilevel systems as the area in complex systems science requiring a major paradigm shift, beyond which significant scientific progress cannot be made." … "…they are systems of systems of systems, and we have no scientific formalism for representing the bottom-up and top-down dynamics of multilevel systems from micro-levels to macro-levels through meso-levels." Simplicial complexes with their related homology and cohomology structures are increasingly being seen as a very promising point of departure for modelling complex systems of systems. They provide a natural generalisation of networks. An abstract p-simplex is defined by p+1 vertices and has a geometric representation as a p-dimensional polyhedron in an n-dimensional space, n ³ p. In a 1952 paper2 C. H. Dowker shows that relations can define simplicial complexes. Inspired by this in 1972 R.H.Atkin published his ground breaking a paper3 in which he showed how ideas from algebraic topology can be extended from physics and applied to model social systems. Hypernetworks provide another extension through the concept or relational simplex in which the relations holding together the vertices of a simplex are made explicit4. This presentation will sketch the theory of hypernetworks and show how they provide a new formalism to represent the bottom-up, top-down, horizontal and diagonal dynamics of multilevel systems of systems of systems. It will be shown that conventional simplicial complexes have representational problems that hypernetworks overcome. It will be argued that hypernetworks are necessary if not sufficient for representing the dynamics of complex multilevel systems of systems of systems.

1. 'Complex Systems Science: Expert Consultation Report', Johnson, Bourgine & Hales (eds), ftp://ftp.cordis.europa.eu/pub/fp7/ict/docs/fet-proactive/shapefetip-wp2011-12-06_en.pdf , 2009.

2. 'Homology Groups of Relations', C. H. Dowker, Annals of Mathematics, 56(1), 1952, 84-95

3. 'From cohomology in physics to q-connectivity in social science', R. H. Atkin, International Journal of Man-Machine Studies, (1972) 4, 139-167

4. Hypernetworks in the science of complex systems, J. H. Johnson, to be published by Imperial College Press, 2012.