# Virtual Communities – Large-Scale Human-Computer Networks

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*Abstract* – **Virtual communities are viewed as large-scale complex systems operating between populations of humans and computers. We analyze these systems using neuropercolation theory, thus extending previous results based on studying spatio-temporal neurodynamics in brains. Phase transitions in spatially extended networks play critical role in robust functioning. We argue that optimally designed human-computer networks must operate near criticality, thus generating the desired fast and reliable operation at large-scales.**

## SUMMARY

TODAY we can witness a paradigm shift in science and technology due to the enormous complexity of the problems researchers attempt to rigorously analyze using powerful digital computers. Virtual communities were nonexistent just a few years ago, but they have explosively expanded in recent years. Virtual communities are examples of large-scale complex systems with emergent behaviors between humans and computers. The forefront of research in this field explores human cognitive functions, both in individuals and in populations of individuals [8, 11, 14].

These are highly nonlinear and nonstationary systems and traditional mathematical tools have limited success in analyzing them. Methods of discrete mathematics, combinatorics, statistics, and the theory of random graphs and networks are especially useful in describing such complex phenomena. Scale-free random graphs and networks pose very difficult mathematical questions. There has been rather little rigorous mathematical work in this area. Progress has been made with scale-free random graph models of large-scale real-world networks. Significant novel results concern inhomogeneous random graphs and their general scaling properties [3]. There is a yet inadequate modeling of dynamic behavior of large-scale graphs influenced by complex topology. Novel mathematical tools are required to rigorously describe these phenomena. Initial steps to this direction are indicated in [4].

This work is based on the studies of brains as large networks in the framework of neuropercolation theory, and extends these studies to networks formed by brains and computers [9,10,12]. There is a critical link between mesoscopic brain activities manifested in the form of wave packets, and macroscopic activities involving the entire hemisphere, measured by brain imaging using fMRI, PET, SPECT, EEG and EMG. The waves often have large-scale, highly textured spatial patterns of cortical activity. Synchronization manifests continuous distributions of activity [8, 11, 13] in cortical neuropil that modulate firings of selected neural networks [5-7].

Neuropercolation theory offers a fresh beginning, in which the discreteness of network connections can be approximated with numerical representations in percolation theory [9, 13]. It is readily adapted to describing microscopic, mesoscopic, and macroscopic levels, and the relations among spatial and temporal variables between levels in phase transitions. Modeling of structural and functional connectivity by neuropercolation theory is well advanced, particularly in modeling the interplay of long connections, inhibitory feedback, and additive noise in the genesis of self-regulated spontaneous activity of large nets of nodes at the mesoscopic level.

The results obtained based on brain studies can be generalized to the description of various networks, including collaborations, school friendships, mobile phone calls, word associations, protein interactions. The explored graphs demonstrate that the web of modules has highly non-trivial correlations and specific scaling properties [1, 15]. Statistical features of populations have been analyzed and clustering properties described [2, 12] leading towards a much needed step to uncover the modular structure of complex systems. Efficient techniques are introduced to explore overlapping communities on a large scale.

Due to the highly interdisciplinary nature of virtual communities and large-scale human-computer networks, major advances must be made in identifying the common language across disciplines, which include physical, biological, social, and behavioral networks. This workshop can play an important role in that direction.

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