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## Spectral properties of complex networks

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### Abstract

On the scale of the past ten years, modern societies have developed enormous communication and social networks. Their classification and information retrieval becomes a formidable task for the society. Various search engines have been developed by private companies which are actively used by Internet users. Due to the recent enormous development of World Wide Web, social and communication networks, new methods have been invented to characterize the properties of these networks on a more detailed and precise level. It is highly important to discuss and develop new tools to classify and rank enormous amount of network information in a way adapted to internal network structures and characteristics. New characterization of complex networks will allow to manage in an efficient and rapid way information extraction for social networks, communication, bio-cell and other networks. Such type of problems of complex networks and Markov chains appear in various fields of science. The development of interdisciplinary approach to complex networks, which combines expertise from computer science, theoretical physics, mathematics, economy and biology, is the aim of this workshop.

*Keywords:* complex networks, Markov chains, Perron-Frobenius operators, Google matrix, spectral analysis, disordered systems, information retrieval, search engines, PageRank, random matrix theory, quantum chaos, directed flows in economy, bio-cell networks

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# 1 Workshop Report

As planned, the Workshop took place at ECT\* during 23-27 July 2012. It attracted 40 participants from USA (3), Japan (1), S. Korea (2), Singapore (2), Argentina (1), France (6), Germany (2), UK (1), Italy (9) and other EU countries. However, the most important point is that the workshop attracted participants from very diverse sciences including theoretical and experimental physics, mathematics, computer science, engineering, sociology, econophysics, as well as industrial/commercial/social companies like Orange Labs (France), Brain Corporation (USA) and Barcelona Media (Spain).

Thus, this workshop probably covered the largest number of related areas during the whole history of ECT\*.

The program and slides of the workshop presentations are available at the Workshop website <http://www.quantware.ups-tlse.fr/complexnetworks2012/>

The main scientific research lines represented at the workshop include: complex network analysis, links characterization, mathematical properties of graphs, PageRank and CheiRank algorithms for information retrieval, spectral analysis of the Google matrix of such directed networks as Twitter, Wikipedia, world trade network, graph-based ranking algorithms, large-scale modeling of the brain, epidemia propagation on networks.

In fact the network analysis finds useful applications in variety of various systems such as:

1st day:

PageRank analysis of network of Hollywood actors network (Vigna), mathematical aspects of disassortativity in large scale-free networks (Litvak), eigenvector properties of complex networks (Wang), entropy on complex networks (Thurner), aspects of degree distributions (Olvera-Cravioto), features of noise on complex networks (Baowen Li), multiplexity of networks (Goh)

2d day:

spectrum and eigenstates of Google matrix of directed networks with links to the problems of quantum chaotic scattering, fractal Weyl law and Ulam networks (Frahm), two-dimensional ranking of software codes, Wikipedia and other directed networks (Chepelianski), democratic ranking of world countries via UN COMTRADE database of world trade (Ermann), ranking of trade products and countries (Gabrielli), analysis of universal features of citation networks (Fortunato and Eom), dynamics for assortative and disassortative networks (Scala), analysis of rumour spreading in social networks (Panconesi)

3d day:

analysis of the SIS N-intertwined epidemic model (Mieghem), tennis players ranking (Radicchi), links analysis of complex networks (Benczur), game of go as a complex network (Georgeot), large-scale modeling of the brain (Izhikevich), percolation on complex networks (Hasegawa)

4th day:

localization and spreading of diseases in networks (Dorogovtsev), statistical analysis of online discussions on social networks (Kaltenbrunner), experiments with quantum microwave graphs (Sirko), structural and geographic properties of online social interactions (Volkovich), dynamics and communities on directed complex networks (Jeong), critical phenomena on complex networks (Bianconi), spectral decomposition and community detection (Galtier)

5th day:

credits and the instability of the financial systems from physicist's point of view (Guhr), random walks on graphs and spectral gap (Zlatic), spectral methods of network analysis (Silvestri), random walks and diffusion on networks (Blanchard).

It is clear that such a broad range of research aspects of modern network analysis requires exchange of expertise from various sciences and the ECT\* provided this opportunity with his

stuff which created a family friendly atmosphere, easy internet access, nice lunches and dinners during the whole workshop period.

According to the opinion of organizers such kind of interdisciplinary workshops fit very well in the scope of ECT\*: nuclear physics opens here new research directions in various sciences (that happened already many times during the development of nuclear physics), it projects its prestige to these interdisciplinary workshops and at the same time it establishes new links between nuclear physics and related areas. This will be profitable in future both for nuclear physics and other sciences.

The attractive aspects of ECT\* are well visible on an example of participants from Asia: they came to the workshop covering expensive travel from their side.

It should be noted that nuclear physics community is relatively healthy and can cover travel and 30 percents of local expenses for 70 percents of participants<sup>0</sup> and 100 percents for 30 percents of participants. However, in other sciences it is usually very hard to find additional funds. So, it may be useful to decide to cover for interdisciplinary workshops 70 percents of local expenses for 100 percents of participants.

It is fortunate that for our workshop two EC grants (NADINE and FOC) allowed to provide additional help (e.g. 3 of organizers had zero support from ECT\*); e.g. all participants from France have been self-supported for 100 percents.

Finally some technical notes: in travel directions for the bus it is useful to note that ECT is on 20 meter distance from the bus stop, otherwise some participants follow forward the road after the bus stop. It is also useful to explain in the ECT\* rules what does it means 70 percents support (e.g. say directly that this means 30 euro for hotel and free lunches and dinners), tell that hotels are about 65 euro/night, lunch is 7 euro and dinner is about 20-25 euro.

Two of us (TG and DLS) participated at ECT\* workshops about 15 years ago and we are pleased to note the great improvements of ECT\* conditions provided for the participants at present compared to these old days (nice halls, modern equipment, easy internet access).