Global brain and beyond: a concerted model of interacting networks

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Abstract. An advanced concerted network methodology with its qualitative description has been proposed as a comprehensive scope of global brain issues. The model includes multiplets of elements (intermediators, boxes, bouquets, stems, beds, layers, nodes, links-bindings, links-connections, and links-dependencies) in order to formalize interactions of human networks with environment infrastructures. Concomitant practical interpretations of global brain network phenomena become easier and clearer through application of the methodology. It is necessary to note that proposed network approach reflects the nature of domain analysis if compare with graphs focusing on formal specificities.

1. Introduction

Following to \cite{1} global brain (GB) is a projected emergence of a new control structure from the coordinated interactions of human and machine agents. In this regard integration of relatively primitive interacting actors forms a kind of a complex network\cite{2}, with advance description through multilayer interpretation \cite{3} or stem network format (figure 1) \cite{4}.

The GB unites all human beings (HB) with the worldwide network of information and communication technologies similar to cortex and concomitant activities of human body. Last decade qualitative and quantitative techniques of complex networks, based significantly on graph theory have been elegantly utilized in brain network organization studies \cite{5}. A practical idea for a collaborative project to create a “Global Brain Network” in which summarized data and computing capabilities provided by lay people has been proposed in \cite{6}. The initiators imply that the resource they develop might be applied effectively and efficiently to solve problems fairly and democratically selected by the contributors. They call their accomplices and partisans to share with.
It is notable that mathematical beauty of property graphs (PGs), multi-relational graphs (MRGs), multi graphs (MuGs), edge-colored graphs (ECGs), hypergraphs (HGs), where vertices interact in group profile rather than that of pair [7] encountered with complexity of practice. All these graphs have demonstrated specific but limited capacities for system analysis so far.

Having been proposed to denote attributes, PGs and MRGs which are powerful per se but overloaded with labels and maps [8], and thus often complicate the issue rather than clarify it. MuGs and ECGs are graphs which are permitted to have multiple edges, but not multiple vertices that limit their capacity. At least one can’t find no phrase “multiple vertices” nor”multiple nodes” with no web search engine. None has ever underlined possibility of such multiplicity in graphs even in most general proper graphs.

Moreover graphs is a platform for mathematicians, even somewhat effective, while complex networks represent multidisciplinary language available for experts of diverse domains who might not be inspired with Path Algebra Operations at all. Additionally, complex networks [9] concept (that comprises a theory and tools both) have operated with dynamic sets of elements and become of interest for analysis of transition processes. It seems of sense to describe cognitive agents of GB and environment elements as actors of different (biosocial and technological) divisions of the complex network.

Interconnection is implied within supposed cognitive activity of the GB network: changes in the biotechnological division activate changes in the social division and vice versa. Such activity has consequences on the dynamic structures of both interconnected divisions.

Development and support of socio-economic and technological structures and their robustness are should be among vital issues of global brain. Even for complex networks which had been studied intensively for a decade, their exploration still concentrates on the platform of single non-interacting network. It has been recognized that there is a need in elaboration in reliable and transparent tools for studying interconnected complex networks [10,11]. The works on property graph approach [12] also try more or less to study problems similar to those successfully solved on the basement of interacting multilayered networks [13,14,15].
2. Model
Further to scientific discussion the authors within existing framework developed and applied a stem network (SN) concept [4]. This concept takes into account intrinsic multilayered thematic and dynamic nature of real multi-actor systems. Multiple nodes of a multiplex networks are called stems. The stem network is described by the triple $B=(S, T, C)$, "bed", where $S$ is nonempty set of stems, $T$ is a nonempty set of thematic layers, $C=(C_1, C_2, \ldots, C_t)$ is a set of binary relations on the $S$, where $C_t$ corresponds thematic layer $t$. In traditional words SN-network is a network which is permitted to have multiple nodes, having multithread links of same nature.

The GB might converge humans, natural and machine agents and must coordinate and connect huge and different varieties of them [1]. In line with the paper [16] just to model GB a combined stem network (CSN) is applied as basic integration of interdependent SN-networks $V=(B_1, B_2, \ldots, B_m)$, described on $m$ "beds" with nonoverlapping sets of stems, thematic layers and binary relations. Some stems from different "beds" might be united into a group which is called a bouquet. Such a group of real objects - multiplet (pair, triple ...) includes nonrepeatable (as a rule) coactive stems of different beds $(S_{ik}, S_{lj}, \ldots)$, where $S_{ik}$ is a stem $i$ from the bed $k$. Thus bouquets are partitioned into stems which firm nodes of networks of the same nature. Links within a stem, between different stem nodes of the same layer of the same network, and between stems taken from different networks are put in different categories. Links - between the stems inside a bouquet represent binary relations (interactions) such as "dependence" (D-links), which differ from couplings - "connections" (C-links) that govern the interaction between the stems of a bed; couplings of "bindings"-type (B-links) describe the relationship between the nodes of the same stem.

The concept categorizes system actors as stems, the latter are stratified into nodes according to each thematic layer. The following example demonstrates the idea of combined stem network.

Thus HB networks incorporate professional, family, and friendly connections. While transportation a container might change airlines, railways, boat lines, bus lines…. Naturally it is impossible to combine human beings with no gadgets by relative links neither gadgets with HB through electric signals. Such a detailing of links promotes clarification while modeling attacks on separate elements of a network (nodes, stems, bouquets, beds, layers, links-bindings, links-connections, and links-dependencies) and their combinations. The novel network concept promotes easier understanding and clarification of the implicit and complicated structure the property graphs propose. Also it is of significance that all the familiar graphs: pseudographs, multigraphs, property graphs, color edged graphs bear no multiple vertices. These graph approaches concentrate on subjects of instrument traits while the combined stem network focuses on subjects of nature.

In order to study the problems of safety and sustainable development of systems it has been important to take into account internal properties of stems - capacities. First, capacities are needed to hold loads in a network in terms of centralities (degree centrality load, bridge centrality load, vicinity centrality load…). Second, those provide robustness while countering diverse attacks.

Time factor $t$ is also included into consideration for reflecting CSN dynamics. Attack schemes of the CSN structures in context of safety problems has been reviewed in frame of a simple analysis of major offensive actions, which are important for studying of GB structures described by combined stem networks.

3. Instruments
To promote the current study we applied Processing 3.x (an open source software) with a library for graph and complex network visualization giCentre [17]. The instrument operates with 2D and 3D rendering engines to portray massive networks in real-time regime and to enforce the exploration performance significantly. This library/software supplies with a flexible and multi-task architecture that actually brings new capacities to work with complex data sets effectively and thus produce valuable visual results. Aimed on thorough understanding of network objects and processes, visualization of large graph entities has been developed for the latest two decades within several successful [18-20]. Visual representations are useful to leverage human perceptual abilities to search
for features in network structures and data. However this process is inherently difficult and requires advanced exploration strategy [21]. As well as being technically accurate and visually attractive, network instruments and tools should be directed toward real-time visualizations and analysis to improve a user’s investigation process. And it is well-known that interactive techniques have been successfully guided by domain experts for complex exploration of large networks.

4. Results and discussion
The proposed model (figure 2) allows the following. Elements of GB network are considered as stems that stand-alone or interconnected and interdependent within and across countries, states, regions, local territories, and sites. Most facilities of technological infrastructures are proprietary of the private sector or federal, regional, or local governments, and might be stratified into diverse layers on pertinent beds while connected to other systems of the same or different field. Thus contrary to traditional complex networks failures and attacks in combined stem network might comprise not only removals of nodes but those of stems and bouquets in whole. It is trivial that removal of a C-link in a stem network does not necessarily tear a path between attached nodes because of B-links. The recent research [22] assumed that elements in the dynamic network can fail independently of other elements (internal failure) or due to external causes (if it has a substantially damaged neighborhood). The study also emphasized a value of spontaneous recovery for the dynamic networks. The CSN approach is able to detail the neighborhood for further analysis of damage and spontaneous recovery processes concomitant to network element fails.

Our model also demonstrates by figure 3 that in case of emergency for a technological node or stem of a bouquet its “conscious” partner stem (human or sensor) is able to give a signal for the system to start an intentional recovery process. All these clarify CSN robustness issues and promote stem network safety strategies. The emerging world society becomes more and more dense. Its stationary or mobile sparse bouquets (dwelling site, work station, transportation unit, unmanned vehicle …) are filling with new artefacts and comprising additional network stems thus to supply HB with new capabilities.

![Figure 3. Three bouquets of two-bed (with two layer multiplexes) combined stem network.](image-url)
Among examples of contemporary complex systems that might be observed through combined stem network prism with their respective beds, bouquets and stems are: Silk Road [23], Smart Home [24], and M2M [25]. Eight Millennium Development goals with 21 targets might be contemplated accordingly as bouquets and subbouquets. A new set of 17 Sustainable Development Goals adopted for the post-2015 development agenda by Special Summit on Sustainable Development in September 2015 [26].

GB as a single entity is especially essential in case it makes interpretation of complexity for networks with communities. They form heterogeneous structures severely different from regular, random or scale-free ones [27]. Global brain is now far from a metaphor [28-29] for the planetary system of ICT networks that interconnects all human beings and their technological appliances. GB modeling evolves comprehensive network that collects, stores, analyses, and processes ever more information. It also strives to take over ever more functions of governance, coordination and communication from public and private organizations, and tends to be “smarter”.

For deeper study Global brain might be modelled by a collaborative combined stem networks (CCSN). In this case some bouquets might be put in one silo according to additional requirements-constraints (for social and communication networks these are geographical, legal, and cultural ones) to form specific groups (rather societies than communities) which might be called boxes. Moreover, often real CCSN demonstrate poor concert because of contradictory constraints of diverse boxes.

The collaborative combined stem network Y is defined as an integration of interdependent CSN-networks $X_i$ ($i=1,2\ldots n$) described on n "boxes" which comprise non-overlapping sets of bouquets, so that $Y \supseteq X_i$. Thus within the box one observes the series of non-repeatable bouquets (multiplets: pairs, triples,...) of non-repeatable of stems from different beds ($S_k, S_l, \ldots$). The boxes are partitioned into bouquets; the latter ones are partitioned into stems which firm nodes of same-type networks. Matchmaking problem has been a ubiquitous one set by mankind for ages and turned out prominent during last decades [30]. The problem is wellknown in economics, medicine, education domains and everyday life as well.

**Figure 4.** Three bouquets of two-bed (with two layer multiplexes) combined stem network.

To provide matching within GB Collaborative Combined Stem Network model it is of value to make the entities understandable for actors of diverse boxes. All the nodes, stems, bouquets of different boxes should be compatible just to make the GB work as a whole organism. Such a compatibility might be provided through special mechanism which implements direct homogeneous
links or those through single intermediator stems, intermediator bouquets, or intermediator boxes (figure 4), and thus composes a Concerted Collaborative Combined Stem Network.

5. Conclusions
An advanced concerted collaborative combined stem network methodology with its qualitative description has been proposed as a comprehensive scope of global brain issues. General terminology has been applied with aim to bridge diverse disciplines and clusters around combined stem networks. The model includes multiples of elements (intermediators, boxes, bouquets, stems, beds, layers, nodes, links-bindings, links-connections, and links-dependencies) in order to formalize interactions of HB networks with environment infrastructures. Concomitant practical interpretations of global brain network phenomena become easier and clearer through application the methodology. It is necessary to note that proposed network approach reflects the nature of domain analysis in comparison with graph tools focusing on the instrument specifics.

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