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Complex Networks Dynamics

Cyrille Bertelle[1,3,a] and M.A. Aziz-Alaoui[2,3]

[1] LITIS, University of Le Havre, 25 rue Ph. Lebon, B.P. 540, 76058 Le Havre cedex, France
[2] LMAH, University of Le Havre, 25 rue Ph. Lebon, B.P. 540, 76058 Le Havre cedex, France
[3] ISCN, University of Le Havre, 25 rue Ph. Lebon, B.P. 540, 76058 Le Havre cedex, France

Abstract. This paper proposes a conceptual approach to study conceptual links in complex systems between dynamics, structure and control. Studies cases are presented and are developed, using a java library on dynamical graphs called GraphStream.

1 Goals, Scientific Position and Approaches

One of the main characteristics of complexity is the emergence of properties, as synchronization, due to dynamical processes. Our objective is to contribute to the formalization of these emergent properties studying dynamical structures. The complexity dynamics is not only a one-way expression of the structure properties, but the structure itself controls the dynamics of the whole. The structures of complexity proposed here, are interaction systems as the core of self-organization mechanisms. During morphogenesis or more generally along morphodynamics, the structure topology is emergent or evolving [2]. Dynamical networks are efficient tools to express some local or global properties of this evolving topology. They capture structural aspects of complex systems representing entities as nodes and interactions between them as links. There are many experimental and analytical evidences that the network topology crucially influences essential network properties, such as resilience and tolerance to attacks, spreading processes, but also the collective dynamics phenomena, such as self-organization and synchronization [1, 10].

Our purpose is to describe complex systems and their constitutive entities as the result of a process coming from the interaction of the three concepts: Structure, Dynamics and Control (see Figure 1). This triangular conceptual model can summerized our approach in modeling various phenomena:

- *Morphogenesis* is the result of dynamical flux on entities leading to an emergent structure under a self-organizational process making co-evoluate entities, strcutures and dynamics.
- *Network synchronization* could be controlled by its topology. We are interesting on understanding how does the network structure impact on dynamics.
- *Topology identification* of network of interacting dynamical systems can be processed by an adaptive control.

We give in section 2, examples of this three-part interacting system of concepts characterizing the complexity of the studied phenomena. In section 3, we describe the dynamical graph library, called GraphStream, allowing to manipulate dynamics of networks involved in the section 2.

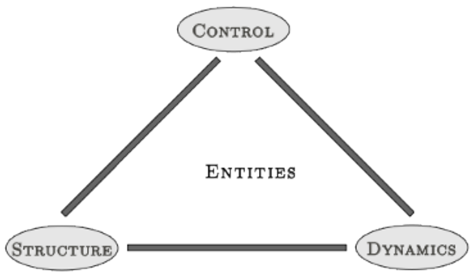

Fig. 1. Complex systems description based on the three-part interacting concepts: Structure, Dynamics and Control

2 Complex Network Dynamics: Applications

2.1 Network synchronization

Synchronization of networks, with nodes corresponding to dynamical systems, leads to relevent applications as in brain dynamics and neuroscience. Various synchrony behaviors can arise in such a case, among them, identical or burst synchronization produced by slow-fast dynamics [3]. The coupling strength of dynamical system for burst synchronization is sensitive to the network topology, like the averge in-degree, described in the Figure 2.

2.2 Community Detection Algorithms on Dynamical Graphs

Community detection on dynamical graphs has practical applications for adaptive computing distribution of decentralized models. In Figure 3, we observe a swarm intelligence process based on a combinaison of cooperative-competitive colored ants colonies[1], and making emerge a

[a] e-mail: `cyrille.bertelle@univ-lehavre.fr`

[1] This original swarm intelligence algorithm on dynamical graph is called AntCO2

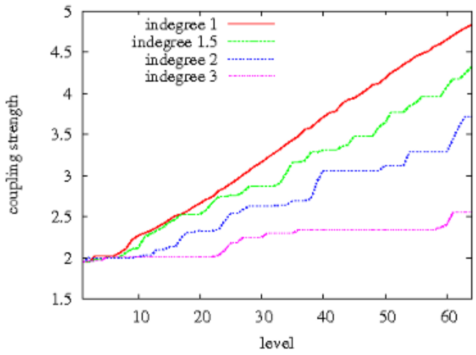

Fig. 2. Coupling strength to synchronize networks with different average in-degree

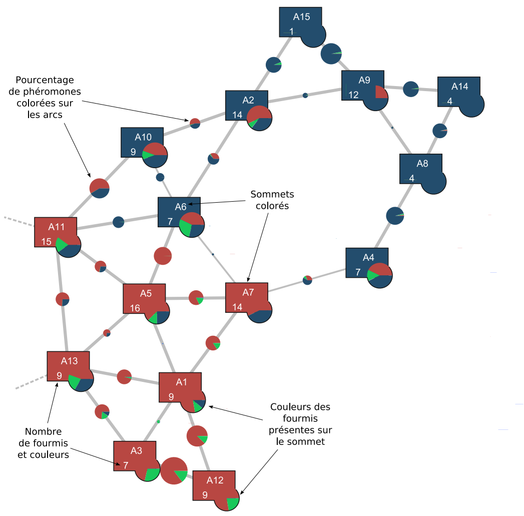

Fig. 3. Graph clustering with AntCO2

dynamical clustering over a dynamical graph describing communications between entities of a program [4].

2.3 Urban Vulnerability Analysis based on Road Network Morphodynamics

Urban population protection during possible technological risks could lead to analyse the road network morphodynamics in order to measure vulnerability during a global evacuation process of a whole city. Figure 4 shows a dynamical process over road network of Le Havre city to detect morphodynamical properties, as element of vulnerabilty measures [8,7,6].

3 A Computing Ressource: GraphStream

The previous applications have been developed with GraphStream[2] which is an open-source java library implemented by the RI2C team of the research laboratory LITIS [5]. The expression of dynamics is the major specificity of this library making simulations based on dynamical graphs. A dynamical graph is basically described by a stream of events, corresponding to additions or removals of nodes, edges or attributes on them. Figure 5 is a two-windows simulation where the left window is the output of an artificial ecosystem where various animal species are crossing space with collective moves following boids algorithm [9]. The rigth window is a dynamical graph composed from the ecosystem simulation, extracting entities and creating the graph of communications between them. During the dynamical graph building a swarm intelligence process is running over it in order to detect communication clusters which are represented by colored nodes and edges. An automatic display is implemented in GraphStream allowing to aggregate high density connected region of dynamical graph. The two curves on the bottom of the right window give two indicators measuring clustering and load-balancing efficiences.

[2] http://graphstream-project.org

Aknowledgment

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[3] RISC is a French Acronym for Complex Networks and Systems

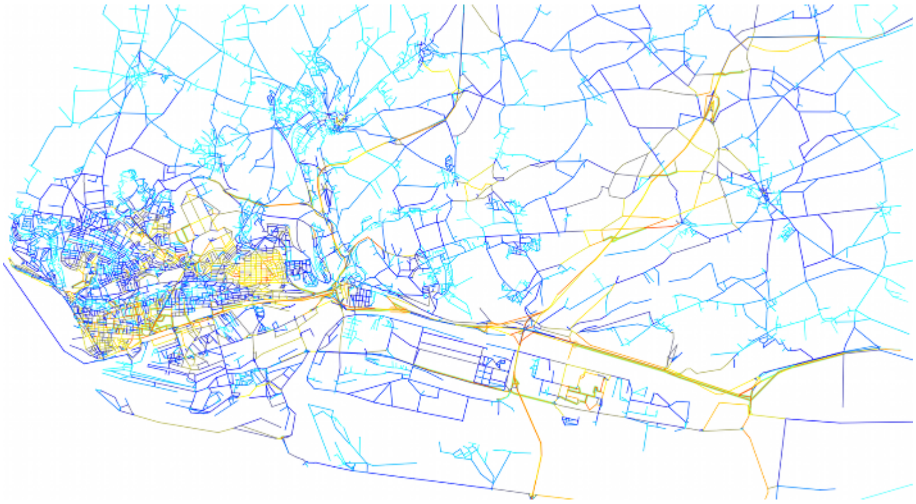

Fig. 4. Morphodynamics of the Road Network of Le Havre City to Study the Urban Vulnerability

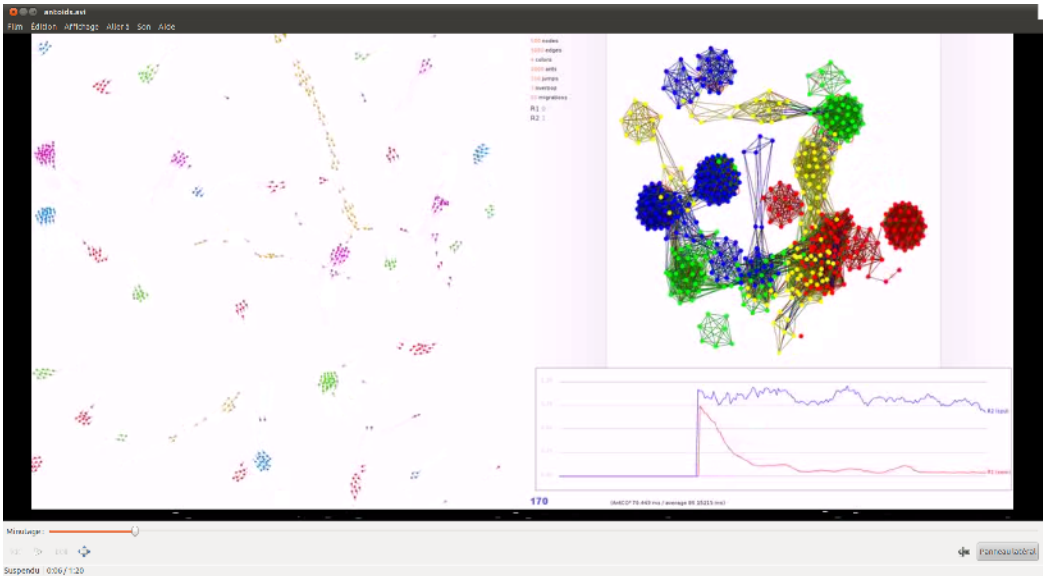

Fig. 5. Adaptive distribution of a dynamical simulation with AntCo2 algorithm implemented in GraphStream Library

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