

GIACS



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GIACS

**General Integration of the Application
of Complexity in Science**

Co-ordination Actions

Research Directorate General

NEST-2003-Path-1 Tackling Complexity in Science

GIACS WP3 – D3.3

**Session in workshop organized to put together
complexity and technology for initiating common PhD
projects: industry-STREPS**

Due date: 2008-07-01

Submission date: 2008-07-01

Start date of project: 2005-07-15

Duration: 42 months

Ente per le Nuove Tecnologie, l'Energia e l'Ambiente(ENEA)

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)

Dissemination Level

PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Introduction

GIACS (General Integration of the Applications of Complexity in Science) was created to coordinate the activities of the Complexity Pathfinder in NEST (New and Emerging Science and Technology).

NEST is a new activity in the Sixth Framework Program (FP6) funded by European Commission. It aims to support unconventional and visionary research with the potential to open new fields for European science and technology, as well as research on potential problems uncovered by science.

The objective of GIACS is to support the integration of NEST [Complexity Pathfinder STREPs](#). These Specific Targeted Research Projects deal with implementing complexity science in various application domains including physical sciences such as physics, chemistry, and biology; social sciences such as psychology, sociology, political science, economics.

The GIACS objectives should be fulfilled by a set of work projects each aimed at accomplishing a sub-missions.

This document describes the activities carried out, in the frame of the WP3 by the CAMO unit (Computing and Modeling) of ENEA, the Italian National Agency for New Technologies, Energy and the Environment.

Third work package: Aim and Deliverables

WP3 makes the connection of STREPs to technological application areas and in particular to infrastructure networks. The effort is to make the connection between real life situations and the Complexity STREPs ideas such as multi-level analysis and network properties.

Three deliverables were set in WP3 for achieving its goals as specified in the following table.

Deliverable No	Deliverable title	Nature	End month
D3.1	Gathering relevant data (people, institutions) for the possible cooperation industry-STREPS.	R	18
D3.2	Support of visits leading to common Complexity PhD industry-STREPS.	R	1-42
D3.3	Session in workshop organized to put together complexity and technology for initiating common PhD projects: industry-STREPS.	O	36

*R report

*O other

The present Deliverable D3.3 due for 14th July 2008 was accomplished on time and the activities done in this time are reported in the following sections.

D3.3. Session in workshop organized to put together complexity and technology for initiating common PhD projects: industry-STREPS

The D3.3. activities are summarized below

- (1) A major task of GIACS WP3 is the realization of a specific event able to group people from the research communities (from different disciplines from physics, to engineering, from economics to social sciences) with Critical Infrastructures stakeholders.

As it has been anticipated in the former Report, ENEA has taken the lead for the organization of the Satellite Workshop "Critical Infrastructures as Complex Systems" (held at a satellite event of the European Conference on Complex Systems in Dresden (October 1-5, 2007), together with dr. Gwendal Le Grand, formerly at ENST Paris and now moved to CNIL Paris.

The proposal of that Satellite event has been accepted by the Conference Steering Committee (see <http://www.trafficforum.org/dresden>) and granted by an amount which has been used to sustain the expenses of some of the Invited Speakers. That amount has been cumulated with a part of the ENEA budget from GIACS project which was purposely allotted to the event organization.

The final Agenda of the event (http://www.ylichron.it/Satellite_ECCE07/agenda.html) is as follows:

Workshop Agenda

Morning Session

Time	Speaker	Affiliation	Title
09:00 - 09:15	V. Rosato	ENEA	Workshop Presentation
09:15 - 10:00	R.K. Iyer	University of Illinois	A Configurable Hardware Framework for a Trusted Computing Base: Application to the Power Grid
10:00 - 10:15	W. Schmitz	IABG	Simulation and Test: Instruments for Critical Infrastructures Protection (CIP)
10:15 - 10:30	H. Dwelling	IABG	Knowledge-based Emergency Management Tools
10:30 - 10:45	M. Salzano	University of Salerno	The Effect of Globalization on Network's Nodes of Different Structural Characteristic: an Heterogeneous Agent Simulation
<i>Coffee Break</i>			
11:15 - 12:00	W. Willinger	AT & T	(White) Lies, Damned Lies, and Statistics: A Critical Assessment of Preferential Attachment-type Network Models of the Internet
12:00 - 12:15	Y. Kajitani	CRIEPI	Modelling interdependencies of critical infrastructures under natural disaster- A case of supply-type and transportation-type infrastructures
12:15 - 12:30	C. Balderer	EHTZ	Repair strategies for minimizing the risk of cascading failures in electricity networks
12:30 - 12:45	L. Buzna	TU Dresden	Evolution of high-voltage electricity networks topology
<i>Lunch</i>			

Afternoon Session

Time	Speaker	Affiliation	Title
14:00 - 14:45	J.C.F. Laprie	LAAS	Modelling Interdependencies between Electricity and Information Infrastructures
14:45 - 15:00	R. Setola	Campus Biomedico	Model Critical Infrastructure via a Mixed Holistic-Reductionistic approach
15:00 - 15:15	C. Chaudet	ENST	High-level modelling of critical infrastructures interdependencies
Posters Presentations			
15:15 - 15:20	L. Issacharoff	TU Dresden	Vulnerability of freeway networks
15:20 - 15:25	M. Schläpfer	ETHZ	Reliability Analysis of Electric Power Systems using an Object-oriented, Hybrid modelling approach
15:25 - 15:30	J. Habenberger	ETHZ	Comparison of Network Methods and the Agent Based Modelling Approach in the Vulnerability Analysis of Electric Power Systems
15:30 - 15:35	A.M. Gadomski	ENEA	Modelling of Human Organization Vulnerability
<i>Coffee Break</i>			
16:15 - 17:00	V. Latora	University of Catania	The Multiple Centrality Assessment
17:00 - 17:30	G. Le Grand	ENST	Workshop's Conclusions

A large number of operators and stakeholders, all over Europe, have been invited to participate and to contribute to the works. Some have accepted and have actively participated to the event. The Workshop booklet with the abstract of all the lectures and the poster is enclosed to the present Report. The booklet of the event is a part of the present document.

- (2) The editor of the scientific journal “International Journal of Critical Infrastructures” (see webpage <http://www.inderscience.com/browse/index.php?journalID=58>) prof. A. Gheorghe has accepted to publish a collection of papers on the theme “Critical Infrastructures as Complex Systems” which the editors of the Special Issues (Rosato, Le Grand, Chaudet) have stimulated to a number of relevant scientists active in the domain. The reviewing process is on-going and the edition of the Special Issue is predicted for the end of 2008.

EUROPEAN CONFERENCE ON COMPLEX SYSTEMS 2007

Satellite Workshop "Critical Infrastructures as Complex Systems"

Dresden, Germany — October 5th, 2007

AGENDA AND ABSTRACTS

Organizers

Gwendal Le Grand
École Nationale Supérieure des Télécommunications (ENST)
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SPONSOR

Project GIACS: General Integration of the Applications of Complexity in Science

GIACS (General Integration of the Applications of Complexity in Science) was created to coordinate the activities of the Complexity Pathfinder in NEST (New and Emerging Science and Technology).

NEST is an activity in the Sixth Framework Programme (FP6) funded by European Commission. It aims to support unconventional and visionary research with the potential to open new fields for European science and technology, as well as research on potential problems uncovered by science.

Workshop Presentation

Critical Infrastructures (CIs) are central systems for ensuring life and services to citizens. They are thus the technological objects at the vertex of the nation's priority scale, as far as protection issues are concerned. CIs are excellent metaphors of Complex Systems (CS). Their structure is a composition of technological elements; their mutual interdependency and their dependence on human-controlled chains lead them to contain all the issues and properties that "define" a Complex System. Relationships between components are non-linear, contain feedback loops, are open systems and, as such, work far from equilibrium; they are a collection of complex elements. CS has allowed tackling, in the last ten years, the analysis of a large variety of systems of different origins (technological, biological, social and others), as shown by the huge amount of scientific literature produced in these years. In addition, major critical infrastructures (such as electrical grids [1, 6, 5], communication networks such as routes and railways [3, 2], information networks such as the Internet [4, 7], etc.) have been analyzed, particularly under the standpoint of their network's topology. Most CIs can be ascribed to the class of systems growing with no external supervision and, as such, their behavior is often indistinguishable from that pertaining to "natural" systems that evolve under the effect of some sort of selective pressure. Aside to basic questions aimed at understanding growth mechanisms, robustness, vulnerability, there is still a number of questions to be addressed by static and dynamic models of CIs:

- the relationship between topological structure and function;
- the assessment of effective "functional" vulnerability;
- the exploration of the functional phase space to detect phase transition and/or critical points;
- fast and reliable decision support;
- reliable reconfigurability.

The technological scenario of CIs is further complicated by the presence of a peculiar feature which accomunate these objects: their mutual interdependency. This term indicates the fact than, more than ever, CIs cannot be thought as stand-alone entities but they are mutually inter-dependent in the sense that a perturbation occurring on one of them might have (small or large) repercussion on the others. These feedback effects lead the study of emergent properties of these systems even more intriguing. The emergence of new effects might be thus associated also to agencies which lie outside the realm of definition and functioning of a given CI and related to malfunctioning in other networks (like, e.g., the catastrophic effects induced by a prolonged electrical blackout on communication networks, whose resulting fault inhibits, in turn, the availability of a communication network allowing tele-controlling and thus needed to perform the necessary actions for restoring the electrical grid). These "perverse" feedbacks are at the origin of the so-called "cascade effects" recorded and analyzed during recent large-scale blackouts, which affected several western countries in recent years (Italian and US blackouts in 2003, Germany-France-Italy blackouts in 2006 and other minor regional events).

There are a number of relevant technological questions arising from stakeholders operating major CIs such as electrical grids, communication networks or transport networks. They are related both to the intrinsic mechanisms ruling the normal activity of these networks and to the exogenous agencies leading to (usually non-linear) perturbation effects.

The main aim of the Satellite Workshop is to establish a link between the basic science community of CS with a management counterpart made of technological operators who must analyse and care for the efficiency of large national CIs.

The advent of new technological scenario (like that described caused by micro-generation for the power grid) opens the way to more deep reflection on ideas and methods that could be used to develop new tools for the control and the management of CIs. Indeed, the EU FP6 program hosted a number of projects aimed at definitely bridging the gap between basic science and technological operations, in this field. Among them, the IRRIS project, whose scientific goal totally complies with the intents of the proposed Workshop. In fact, IRRIS is an Integrated Project grouping the major institutions and some European CI stakeholders. It is aimed at increasing dependability, survivability and resilience of these information-based infrastructures through, among others, the development of a "Middleware Improved Technology", a collection of software components facilitating IT-based communication between different infrastructures and different infrastructure providers, by supporting recovery actions and increasing service stability in case of critical situations. In this contest, IRRIS is going to stimulate the interaction between the scientific and the technological communities around the problems opened by the complexity of CIs. Actions and programs devoted to these problems are also forecast for FP7. The proposed Workshop would also provide a dissemination forum to let the scientific community aware of these problems and to stimulate the creation of scientific and technological groups ready to take the challenges.

This one-day Workshop, structured around a few Invited Speakers, will present the major problems and the on-going challenges in this area. They will be part of EU and non-EU consortia that are involved in producing new instruments for the modern control of CIs; many of them based (or using) CS ideas and methods. We will also provide an opportunity to other scientists to present original works. A further purpose of the Workshop is also to establish a two-way connection between Science and Technology:

On one side, technology and CI operations will present their problems to the CS scientific community. On the other side, scientific community, which has been attracted by these problems, might have the opportunity to explain, to a wider audience, the results of their analysis, which might open new frontiers in the field of analysis and control of CIs.

Among the scientific themes which would be touched by the Workshop we will quote, hereafter, a (non exhaustive) lists topics:

- Topological properties of critical infrastructures networks; this subject has been among those used as a starting point to introduce CS issues into CI analysis. To date, many different CI worldwide have been analyzed (electrical grids, the internet, social and economic networks etc.); these studies allowed to achieve significant results, on both basic science and technological aspects of CIs. Topological analysis has been also coupled to vulnerability assessment of CIs, with significant results.
- Modeling & simulation of critical infrastructures; this subject is particularly relevant as

there is a wide tendency to couple static (topological) to dynamical models of functional networks to produce "behavioral" models of CIs which might provide also qualitative information of their functioning, establish the onset of critical or emergent phenomena etc.

- Phase transitions on complex infrastructures; this is a territory, typical of theoretical physics, which assumes a paramount relevance in the area of analysis and control of CIs. Phase transitions (like, e.g., congestion in TLC networks or jams in traffic networks) are related to the issue of the "intrinsic" technological limits of CIs, whose causes must be understood in order to prevent their occurrence.
- Modeling interaction between complex systems; this is a "hot" topic which resumes the to date problem which should be faced, which leads CI to enhance their level of criticality with respect to citizen's life. A comprehensive modeling of large scale CIs is needed; basic science should be encouraged to deploy all its "reductionist" capability to attempt to give an answer to that need.
- Emerging behavior caused by infrastructure's interdependency; this issue can be tackled by combining dynamical models of CIs and the modeling of CI's interactions. This is also a theme which could have a major technological interest for CI's managers.
- Real systems scenarios; this should represent the "technological" viewpoint, where stakeholders should provide the up-date of the methods and the tolls which are currently used for the management of the operations on large scale CIs and present which are the type of "crisis" which these tools are called to solve.
- Trust and information exchange between infrastructures; this topic is critical since it provides the input to models and simulators that analyze or represent the behavior of the infrastructures.

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10:15 - 10:30	H. Dwelling	IABG	Knowledge-based Emergency Management Tools
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<i>Coffee Break</i>			
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Simulation and Test: Instruments for Critical Infrastructures Protection (CIP)

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Critical infrastructures (CIs) have undergone drastic changes in the last decades. The ubiquitous use of ICT has pervaded all traditional infrastructures, rendering them more intelligent, increasingly interconnected, complex, interdependent, and therefore more vulnerable. Critical infrastructures are vital backbones of modern societies and our society is fully dependent on them. Besides the traditional threats like natural disasters, man made disasters and terrorist attacks the complexity of the system of interdependent infrastructures has to be considered as an additional threat. The increasing IT-penetration leads to interdependencies and feedbacks which make more and more difficult to distinguish cause and effect. That means, critical infrastructures have to be designed as fault-tolerant systems. Redundancy and self-healing are approved design principles. But such design principles cause increasing costs, and the private sector complying with the rules of shareholder value has to prevent costs. On the other hand security of critical infrastructures has a high societal importance. That means new business models and security technologies have to be introduced that fulfill the interests of the private enterprises and the state. In addition novel security technologies like Modelling and Simulation (M&S) have to be developed and used in order to protect critical infrastructures as well as to train people responsible for safety and security.

Knowledge-based Emergency Management Tools

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Critical infrastructures (CIs) have undergone drastic changes in the last decades. The ubiquitous use of ICT has pervaded all traditional infrastructures, rendering them more intelligent, increasingly interconnected, complex, interdependent, and therefore more vulnerable. Critical infrastructures are vital backbones of modern societies and are increasingly depending on IT and communication networks. Due to the increasing IT-penetration CIs are more and more connected with each other with advantages and disadvantages. Due to this interconnection critical infrastructures can provide their services more cost-efficiently. On the other side in case of disturbances their behavior can not ever be mastered as the large blackouts in USA and Europe have shown. Increasing complexity and manifold conventional and emerging threats jeopardize the system of mutual dependent critical infrastructures. CIP gains a high importance and has to be understood as a holistic process considering technologies and persons acting within this system of systems.

Decision support tools, modelling & simulation, experimentation and training gain a high importance to develop, improve and validate CIP concepts.

The EU project IRRIS is developing decision support tools (DST) and executing simulation experiments in order to test DST and validate the concepts. Based on black-out scenarios the influence of selected DST will be demonstrated.

The analysis of blackout scenarios shows, that a narrow time window is available ? in many cases shortly before the blackout. Within the time window, suitable measures for prevention or mitigation of cascading effects can be taken, provided, that the situation has been assessed well. It is a precondition, that the necessary information about the situation to be assessed is timely available and the decision-making process is supported by suitable tools.

For this purpose IABG develops the expert system *Crisis Prevention and Planning System* (CRIPS). The aim of CRIPS is to minimize the danger of black-outs by:

- Assessment of the current situation
- Support of the decision making in Emergency management
- Warning and Alerting, including the broadcasting of the decisions.

The paper will describe a simplified but sufficiently complex scenario in order to demonstrate above mentioned CRIPS abilities taking into account dependency structures of the two infrastructures electricity and telecommunication. Scenario, emergency management tasks, selected functionalities and solution strategies of CRIPS will be presented.

The Effect of Globalization on Network's Nodes of Different Structural Characteristic: an Heterogeneous Agent Simulation

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Globalization is much more than an economic phenomenon and has non-economic consequences. Studies on globalization follow two main lines. While most pro-globalization advocates examine the impact of external or openness factors, anti-globalization advocates focus on economic sectors that have lost out in the process of globalization. Many globalization indices have been constructed. Generally, they are based on a number of external economic factors, typically trade and foreign direct investment, while scarce attention has been given to the internal factors. This is true both for the effect of such factors on the capability of a country to be in the global market and on the effect of globalization on them. Vice versa, in an evolutionary context these factors can be interrelated with both present and future welfare of the country. Indigenous factors that are positive from an international integration can complement the successful performance of economic openness and be integrated in the process. Those that are marginal for such a process would remain more and more marginalized.

To understand these aspects a network approach could help. But, while it is well known that growth models of the informatics? type ?are quite inappropriate as models of the growth of social networks, for a number of reasons? few points are considered about economic network and especially global economic network. Of course, neither the characteristics of the informatics? type of models or that of growth models of social networks, seem to be adequate for dealing with the evolution of economic networks, especially in a context of globalization, for a number of reasons. The topic most considered about globalization is that of research and knowledge. Very few works about economic globalization as the evolution of a network seem to exist. One of the few exceptions is the work by Kali and Reyes (2006). They combine data on international trade linkages with network methods to examine the global trading system as an interdependent complex network, and suggest new network based measures of international economic integration. They apply existing ideas in the network literature for studying and measuring globalization.

Our work will attempt to deeply address the study of network structures that can be at the basis of globalization. A simulation model, based on NetLogo will be used to show which characteristics must be considered for a new node to be attracted from a pre-existing network and when a link can be broken. We will take specific account of worker-consumer agents and their different characteristics ? marginal and integrated agents. Globalization implies that firms and individuals are interrelated in a multilevel network. At production level, firms look for partners, but they also look for workers. At the distribution and resource level firms look for customer while workers look for work. And so on. The Bianconi & Barabási (2001) competition (the rate at which nodes in a network increase their connectivity depend on their fitness to compete for links) seems to apply in this case, but given the multilayered networking some deeper consideration of its consequences on the structure, robustness, and

especially the effect on the welfare of marginal workers seems possible. This deepening could try to clarify the usual Janos-characterization of the debate about globalization. Moreover, it could help to a better understanding of the resurgence of financial extreme events in the globalization scenario. Are they more or less possible; is the network configuration still presenting a power law both in the case of production and of distribution-resource network and what could be the possible consequences on the financial sector?

(White) Lies, Damned Lies, and Statistics: A Critical Assessment of Preferential Attachment-type Network Models of the Internet

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The author will discuss some of the main problems and challenges associated with measuring, inferring, and modeling various types of Internet-related connectivity structures. To this end, I will use some known examples to illustrate the need to (i) understand the process by which Internet connectivity measurements are obtained, (ii) explore the sensitivity of inferred graph properties to known ambiguities in the data, (iii) be more critical with respect to the dominant, preferential attachment- type network modeling paradigm, and (iv) be more serious/ambitious when it comes to model validation. Ignoring any of these issues is bound to produce results that are best described by the well-known aphorism "lies, damned lies, and statistics."

Modeling interdependencies of critical infrastructures during natural disasters – A case of supply, communication, and transportation infrastructures

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Recently, interdependency analysis (or interoperability analysis) of critical infrastructures has attracted considerable amount of attention from governments, infrastructure operators, and risk management specialists in several countries. This is because there have been many infrastructure system failures and cascading impacts among different systems throughout the world in the past few years. These failures were caused by various complex factors, such as the expansion of infrastructure systems, concentration of population and city assets and poor maintenance due to financial pressure, as well as multiple triggers, such as human error and natural disasters.

It is necessary to understand the reasons for interdependency failures among infrastructure systems. Several ongoing projects are tackling this complex interdependency. In many cases, multidisciplinary approaches are necessary because these interdependencies have various aspects such as physical, functional, social, and economical.

However, majority of the interdependency analysis of critical infrastructures remains at the qualitative level, and quantification strategy is critically lacking. In this study, quantitative analysis is conducted to estimate the service level of each critical infrastructure at each location and time during a failure as well as their consequences (social and economic losses).

This paper introduces the methodological challenge of identifying and quantifying the interdependencies among several critical infrastructures. First, interdependency structures during a natural disaster are modeled based on past events, considering supply (electricity, water, and gas), communication (internet and telephone), and transportation infrastructures (road networks). Interdependencies are defined with respect to physical, functional, and socioeconomic interrelationships. A quantification strategy is then introduced based on empirical surveys and economic models. As a case study, the developed model is applied to the 2004 Mid-Niigata earthquake, which severely damaged infrastructure systems in the northern mountainous region of Japan.

Repair strategies for minimizing the risk of cascading failures in electricity networks

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In industrialized countries, a reliable supply of electrical energy is taken for granted. In order to guarantee a stable energy supply also in case of non-serious failures of electrical equipment, the underlying electric power network has been designed with redundancies. Nevertheless, major blackouts of the transmission grid occur all over the world. They are typically caused by a sequence of cascading failures and may be evidence of a critically loaded transmission system. Furthermore, the increasing trade in electricity ? a consequence of the liberalization of the energy markets ? has led to an additional load of the existing infrastructure. As a consequence, the reliable operation and maintenance of the electric power grid at minimum cost is an increasingly demanding task.

The goal of our work is to develop repair strategies that minimize the risk of cascading failures. A power operator has generally not enough time to re- pair failed lines once a cascade has started, because cascading failures typically evolve in time scales of seconds and minutes. Consequently, we focus on repair strategies during normal operation. Even during normal operation, there are typically some lines that are not operating due to random failures or maintenance work. While the system may still have enough capacity to transmit the power demand, the average loading, and therefore the blackout risk, increases with every failed line.

As it is very difficult to quantify the overall risk of blackouts due to cascading failures, we first develop a blackout model that allows us to improve our understanding of cascading failures and will later serve as a test environment for our repair strategies. We define a model based on the DC power flow equations, where the initial failures are modeled by an independent probability of failure for each line. If a line becomes overloaded due to the initial failures, its probability of failure grows linearly with the amount of overload. This leads to an iterative process that runs until the

We investigate the model on the three area version of the IEEE Reliability Test System 1996. The simulation results indicate that the average blackout size strongly depends on the loading of the system, which is characterized by the relationship between the amount of power served and the capacity of the power lines. At low loading, the distribution of the blackout size has an exponential tail. At a so-called critical loading, however, the tail of the blackout size distribution follows a power law. In this case, the available reserve capacities on the lines are not large enough to prevent cascading failures due to random failures. These results are in agreement with the observations from real blackout data and experiments.

We define a simple repair strategy, which is based on the algorithms mentioned in the article. The quality of this strategy is evaluated by testing its ability to prevent blackouts due to cascading failures. For this purpose, we extend the blackout model by a repair process that can fix a line in each iteration. The simulation results on the IEEE Reliability Test System 1996 show that with our strategy, we can delay the start of a cascading failure up to five times longer than by repairing a line at random. From the simulation results, we conclude that our strategy provides a good starting point for the development of repair strategies in electricity networks.

Evolution of the topology of high-voltage electricity networks

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The electricity network represents an example of an evolving complex system. The first local networks contained only a few nodes, but within several decades they have evolved into a highly connected continental system. The growth of these network was influenced by various factors such as economy, demography, politics and technological developments. In this paper we analyze the growth of the French 400 kV electricity transmission network from its establishment in 1960 until the year 2000. We study the different topological characteristics describing the intensity of the growth process, such as number of nodes, number of lines, average node connectivity and overall length of wires. We compare these results with several economic and demographic indicators in order to identify factors which correlate with the growth rate of the electricity network. Apart from this we evaluate how the topological efficiency and vulnerability measures (clustering coefficient, information centrality, betweenness centrality) evolve in the course of time. Decisions regarding the power grid topology are influenced by many, very often contradictory factors such as, costs, size of covered area, demand, fault tolerance, reliability and quality of service. Our results yield a deeper insight into the process of CI construction.

Modelling Interdependencies between Electricity and Information Infrastructures

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The aim of the presentation is to provide qualitative models of two interdependent infrastructures: the information infrastructure and the electricity infrastructure. The interdependencies of these two infrastructures are increasing due to a growing connection of the power grid networks to the global information infrastructure, as a consequence of market deregulation and opening. These interdependencies increase the risk of failures or disruptions.

The presentation will focus is on cascading, escalating and common-cause outages, which correspond to the main causes of failures due to interdependencies. The infrastructures are modeled globally, not explicitly modelling their components. The models describe scenarios that are likely to take place when outages occur. Both accidental faults and malicious attacks are considered.

Model Critical Infrastructure via a Mixed Holistic-Reductionistic approach

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Many technological infrastructures in Developed Countries, even if generally designed as autonomous systems, have become in the last years largely coupled and interdependent. Hence, to correctly figure out the behavior of the whole system, it is mandatory to model the system of systems composed by the set of different and heterogeneous infrastructures.

This model is generally obtained decomposing each infrastructure into its macro-components and investigating the relations that tie them. Indeed, roughly speaking, each macro-component needs to properly work resources or services supplied by other components and contributes to the production of goods and/or services. Analogously, the presence of a failure (e.g., a fire) may spread from one macro-component to its neighbors affecting their capabilities and, eventually, can be transmitted to further elements. Then, one could think to capture the behavior of the whole system starting from the knowledge of each macro-component's dynamic.

Unfortunately, this reductionistic approach appears, in many cases, not completely adequate or simply too complex. Indeed, services provided by a large class of infrastructures (e.g., TLC services, Internet, etc.) are more easily, and for some aspects more correctly, described as an unicum, a single bundle provided by the infrastructure, instead of the simplistic juxtaposition of many technological components. This changes of perspective can be motivated thinking that this approach allows an enrichment of the model to include also aspects like redundancy, prioritization strategy, reconfigurations that are very difficult to capture when the view is focused on the behavior of the single atomic part of the system.

Even if this holistic approach is very useful to describe the "active" dependencies, i.e., the services provided by the infrastructure to the other elements, it appears unable to handle "passive" dependencies and, more in general, interdependency phenomena.

In this paper we propose the Mixed Holistic - Reductionistic (MOR) model that fuses into a single model the positive characteristics of both holistic and reductionism approaches. MOR adopts macro-components decomposition but analyze the atomic behavior of these components on the base of characteristics and services provided by the different infrastructure managed as single entity. In this way, MOR overcomes the previously mentioned drawbacks.

Specifically, in our model, each infrastructure is decomposed into its macro components and each one is described with a "reductionistic" philosophy on the base of the availability of resources, services and taking into account to the presence of failures. However, to describe how these resources/failures are provided to each single macro-component, MOR considers an holistic model of the different infrastructures where global parameters (e.g., QoS) are evaluated and used. In this way two point of view are simultaneously and concurrently present into the model for each element: the reductionistic one primarily devoted to capture the influence that other elements exert on its capability to correctly operate, second, the holistic vision, specifically used to figure out how different services are provided by each single component. Obviously, the two aspects are strictly related being any infrastructure composed by different macro-components that, individually, are supposed to correctly operate and, on the other side, to cooperate among them.

In the paper we will describe how MOR can be successfully applied to model a real-test bed scenarios focused on an Italian region where the electric power grid and wireless and wired communication networks are tightly coupled.

High-level modelling of critical infrastructures interdependencies

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Due to the increasing concerns in services' quality and to the growing concerns about external threats, the protection of critical infrastructures has attracted much attention from the research community lately. Many research projects involving actors from the academic and industrial fields have been initiated to identify and understand the potential risks that these networks face and to derive parades from these analysis.

In this article, we study the effect of interdependencies that can occur between two of these infrastructures: the telecommunication networks and the electrical network. Each of these types of networks highly depends on the other. A failure of some component in one of these architectures may provoke a fault in the other, for example, when an electrical outage occurs, routers may be switched off as soon as their battery has depleted. Usually, infrastructures know how to self-repair, provided that redundancy offers opportunities to cicatrize the architecture. However, in some cases, these mechanisms may be misled by a wrong interpretation of information. For instance, the lack of reception of monitoring messages for a part of an electrical infrastructure may indicate either a real electrical failure,

or a failure of the telecommunication network. These two causes are indistinguishable and lead to the same response.

In this article, we study these cascading phenomena from a high level of abstraction, using classical modeling tools such as graph theory. We analyze, on potential topologies, the effect of simple failures, derive potential risk scenario and guidelines of some strategies that operators may apply to prevent such cascading failures.

Vulnerability of freeway networks

Limor Issacharoff, Martin Treiber and Dirk Helbing

In this study we analyze the primary road networks of Germany, Italy and France with respect to structural and dynamical vulnerability. The road networks are reduced to the form of weighted and directed graphs. Links represent road segments and their capacity is the links' weight. Nodes represent the main entrance and exit points of the freeways and are associated to the city they lead to (or from). These nodes are referred to as the "city nodes". A second type of nodes is the "junction node" which represents the intersection points of different roads. Traffic can enter or exit the network only via city nodes. To simulate traffic on the network, we use the classic 4-steps model which reduces in the case of freeways to trip generation, trip distribution and route assignment. Trips are generated according to the assumption that the out-going and in-going flows are equal. The flows between cities are the distributed according to the Logit model and assigned to alternative routes according to the Wardrop user equilibrium principle. To assess the network's vulnerability we define suitable topological and dynamical measures. The respective vulnerabilities are then assessed by cutting one or more of the networks' links and by observing the resulting changes in the efficiencies measures. We compare the response of the different networks and evaluate which of the systems is more vulnerable. Based on the results we point out the critical properties of the system which influence its vulnerability most.

Reliability Analysis of Electric Power Systems using an Object-oriented, Hybrid modelling approach

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In the near future the European electric power infrastructure is expected to undergo major changes on both the physical and institutional level. The ongoing liberalization is leading to a fragmented market structure with numerous competing players, associated with extensive trading over large distances while the systems become operated at the edge of the security margins. The integration of distributed generation (DG) and renewable energy sources implies a less predictable generation fleet and a higher volatility of the power flows over the network. With respect to reliability assessment studies, this evolution brings about the need to handle an increasing amount of uncertainties and to consider complex and thus hardly predictable interactions of technical system components and relevant actors.

This paper presents an object-oriented, hybrid modeling approach combining Monte Carlo simulation and the agent-based modeling (ABM) technique in order to assess the probability of cascading failures within complex, networked technical systems. With respect to the power system, agents represent both technical (e.g. generators) and non- technical components (e.g. grid operators) and interact with each other directly (e.g. via the generator dispatch) or indirectly (e.g. via the physical network). This allows to integrate a broad spectrum of different stochastic phenomena and to simulate hardly predictable, time dependent event chains. The modeling approach is demonstrated by performing simulations on the IEEE Reliability Test System ?96.

Comparison of Network Methods and the Agent Based Modelling Approach in the Vulnerability Analysis of Electric Power Systems

Jörg Habenberger and Markus Schläpfer

Networks methods are an accepted approach in the vulnerability analysis of electric power systems. These methods use algorithms and parameters based on the graph theory (average path length, clustering etc.) to evaluate the weakening of a network when branches or nodes are removed. Unfortunately there is no direct link between these parameters and the actual losses or damages in a power grid. In the presentation a comparison is given between the average path length and the loss of capacity in an affected network. For the calculation of the loss of capacity and the average path length the IEEE-Test-System is used and analyzed by the Agent-Based-Modeling approach and the Dijkstra's algorithm respectively.

Modelling of Human Organization Vulnerability

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Critical Infrastructures are composed with two closely interrelated systems. The first usually consist of technological territorially distributed technological network, and the second is the network composed with human organizational units. In practice the critical technological networks are supervised, managed and governed by intelligent entities including individuals, their organizations and all are influenced by requirements and expectations of the society, represented by stakeholders, policy makers and politicians. The state of these actors determine the criticality of the whole infrastructures services, their robustness and the efficacy of resilience in emergency situations, as well as, are frequently the causes of the organization vulnerabilities leading to serious large-scale human errors.

Human organizations are complex from their nature and their efficacy and vulnerability closely depends on the decision-making of their managers, it means on its socio-cognitive and organization factors. The paper deals with the methodology of identification of the sources of vulnerability in human organizations. The main attention is on the socio-cognitive properties of complex large human organization whose mission is emergency management.

The work is focused on the demonstration how an unified computational methodological approach can be applied and used for the modeling of the vulnerability on individual, inter- and intra-organizational decisional levels in case of human-caused threats and organizational crisis. The systemic socio-cognitive paradigms and the framework of the TOGA (Top-down Object-based Goal- oriented Approach) meta-theory is described and applied as a meta-ontological platform and basic formalization and problem structuring methodology, as well as, for the problem goal-oriented redefinition, applying generic domain-independent systemic terminology.

The top-down paradigm relies on the metaphoric assumption that independently on the real complexity of a system, from the sufficient distance it is perceived as a simple object. Goal-oriented rules enable to select only these attributes of organization which may leads to a vulnerability, and object-base conceptualization provides unified computational representation for the problem identification and possible simulations. Some top modeling results related to the recent main natural and technological disasters, such as Katrina, Tsunami, Italian blackout, Chernobyl, illustrate the application of this approach.

The presented work has been performed in the frame of two ENEA's projects, national and European Commission, subsequently, in CRESCO (Centro Computazionale di Ricerca sui Sistemi Complessi), sub- project Soc-Cog CRESCO (Modeling of Complex Networks seen as Socio-technological Aggregates), , and in frame of RTD IRRIS (Integrated Risk Reduction of Information-based Infrastructure Systems).

The Multiple Centrality Assessment

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We present a new method, named Multiple Centrality Assessment (MCA), for mapping centrality in urban networks. MCA makes it possible to ascertain how each street is structurally central in a city according to several different notions of centrality (namely closeness, betweenness, straightness and information), as well as different scales of being central. Spatial distributions of centrality allow an extended comprehension of the city structure, nicely capturing the skeleton of most central routes and sub-areas, and are able to characterize different classes of cities, such as planned cities and self-organized cities. We also investigate how much higher street centrality statistically determines a higher presence of activities (shops and services). Results offer evidence-based foundations of a high level of correlation between the centrality of streets, especially betweenness centrality, and several other urban dynamics like traffic flows and the location of shops and services as well as that of workplaces. These results support the predictive capability of the MCA model as a tool for sustainable urban design. We finally discuss a professional application of the MCA to the restoration of the network of paths and open spaces in the Parma (IT) University Campus.