SIMULATION: A TOOL FOR INTERDEPENDENT CRITICAL COMPLEX SYSTEMS ANALYSIS

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Agenda

- Preamble
- Why simulation
- How to use simulation in Critical Infrastructure Analysis
- Simulation approaches & projects
- What we can do for simulation (Challenges)

Preamble

- "To model a system is to replace it by something wich is
  - (a) Simplier and/or easier to study and
  - (b) Equivalent to the original in all the important respects".

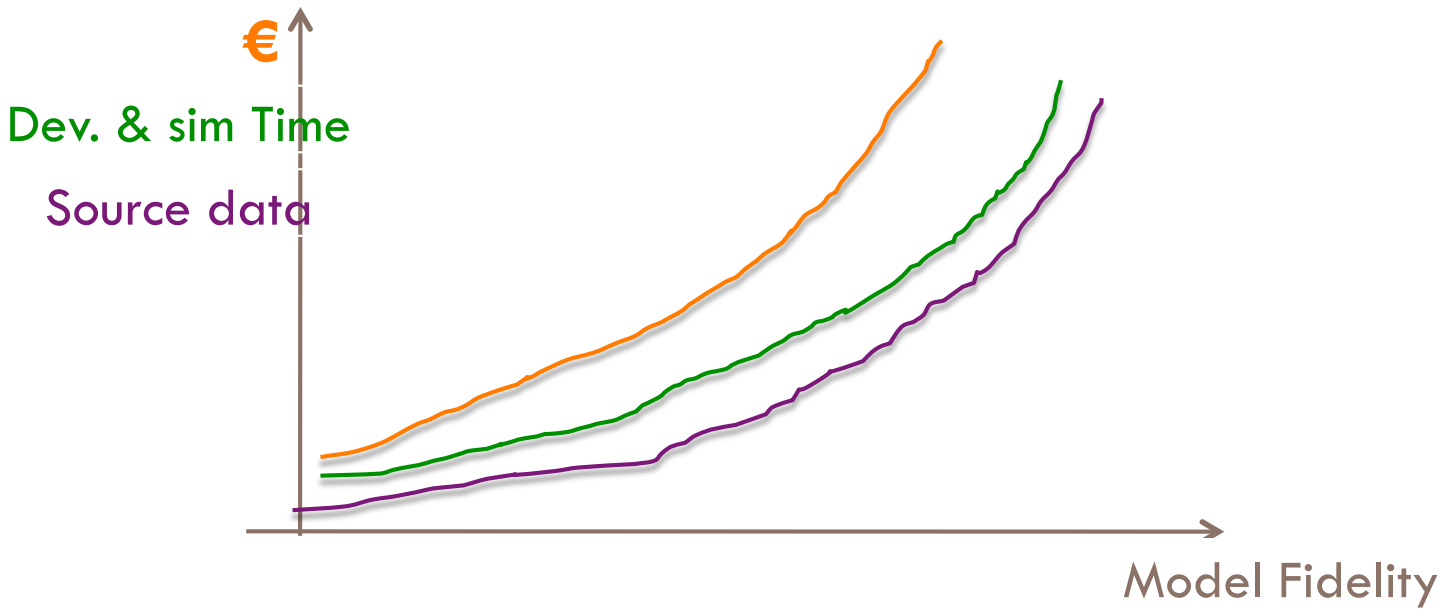
Simulation techniques for discrete event systems,
I.Mitrani, Cambridge university press

- Simulation is a techniques that use computers "to imitate, or simulate, the operations of varius kinds of real-world facilities or processes. The facility or process of interest is usually called a system…."

Simulation modeling and analysis,
A.M.Law and W.D.Kelton, McGraw Hill Int.

Why simulation

- Mathematical models typically made assumptions that are far from reality
- Simulation models allows to reproduce the reality at different level of fidelity
- ***but….***



We need both: from HiFi Simulation to Abstract mathematical models

- High fidelity models of individual infrastructures
  - to understand changing in conditions or behaviour
- System models of aggregate infrastructures supply and dynamics
  - to indentify important interaction and feedbacks and
  - their effect on system operation
- Generic high abstracted complex networks models
  - to identify vulnerabilities of different networks (physical, social, logical) topologies to disruption and effective mitigations

How to use simulation in Critical Infrastructures analysis

- Predictive (“what if”) and prescriptive (“goal-driven”) analyses
- Discovery based analyses
- Probabilistic analyses
- User behaviour evaluation (and behaviour impact on infrastructure usage)

Predictive and prescriptive analyses

- Evaluation of Cascading impacts
- Node State evolution (analysis of events pattern)
- Mission assurance evaluation
  - How does the events effect mission capabilities
- Examples
  - Analysis of crude Oil Supply Disruption, analysis of the effects of tightening of the international crude oil market and loss of import capacity.
  - analysis of timing, magnitude, distribution and duration of potential economic impacts and propagating effects for identified disruption scenarios.
  - Analysis of reaction and recovery capacity to Hurricanes, Flooding, earthquake, etc…

Discovery based analyses

- Evaluation of interdependencies as causes (events) – effects (outcomes)
- Example
  - Weighted ranking of critical subnetworks
  - Analysis of Influenza: vaccination rates, vaccine effectiveness, strain virulence, effects on public health and other infrastructures
  - Economic policy-related analysis:
    - Which industries and economic regions are affected most by an infrastructure disruption?
    - How do infrastructure constraints or industry constraints prolong economic recovery?
    - Are small firms hurt more than large firms? Which are most influential on economic stability?
    - What are the most effective loss prevention and mitigation strategies for individual firms?

Probabilistic analyses

- Evaluation of optimal infrastructure assets to protect from attack or restore in a disaster situation
- Risk analysis
- Effect of alternatives in transport routes or modes
- Example
  - Analysis and optimization models of:
    - Railroad Network
    - Air Transport
    - Other transportation networks

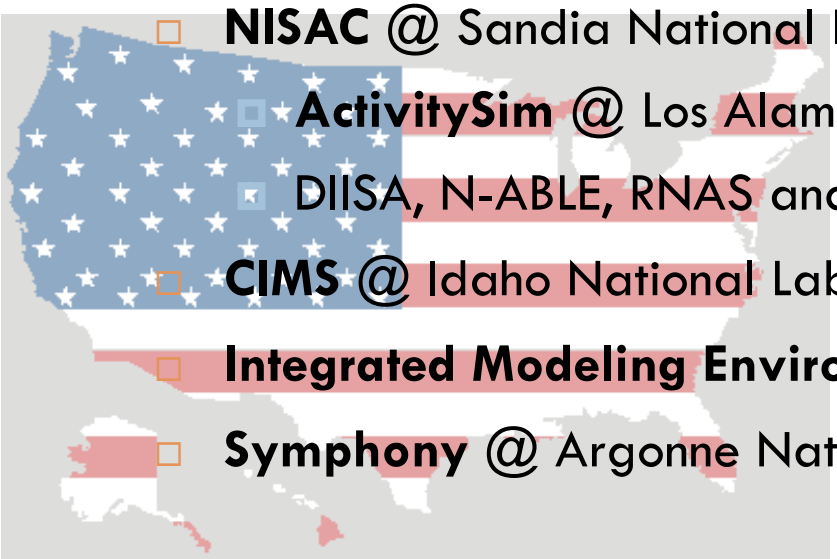
User behaviour evaluation

- Modeling and analysis based on fuzzy human behaviour models and cencus data
  - E.g. to evaluate behaviour impact on infrastructure usage both in normal and critical situations

Modeling and Simulation of Critical Complex Systems:

Existing Solutions

- **CRESCO** @ ENEA, CRIAI, … (IT)
- **CISIA** @ Campus Biomedico (IT)
- **Federated ABMS** @ University of Rome "Tor Vergata"
- **DIESIS** @ ENEA, IC, TNO, Fraunhofer,… (EU)
- **SimCIP (IRRIIS)** @ ENEA, Fraunhofer, VTT, TelecomParis, Siemense, Telecom, IABG, ETH, City,… (EU)



- **NISAC** @ Sandia National Laboratories
- **ActivitySim** @ Los Alamos National Laboratories (USA)
- DIISA, N-ABLE, RNAS and ATOM, N-SMART, IEISS, WISE, UIS
- **CIMS** @ Idaho National Laboratory (USA)
- **Integrated Modeling Environment** @ UNC Charlotte
- **Symphony** @ Argonne National Laboratory, Uchicago

Comparison: Technologies/Goals/ limitations

Project	Technology	Goals	Limitations
CIMS®	Agent-based, graph based, Federated Simulation. GA/DSS	- High portable and visual tools for displaying interdependencies weaknesses and vulnerabilities - High level modeling and simulation for on-the-fly model building and timely 70% solutions - mission assurance; Mission assurance includes the analysis of risk and impact that events place upon such capabilities	N.A.
ActivitySim	Agent-based, parallel simulation	Daily activities modeling and simulation to understand infrastructure networks demand profile	Model Re-engineering
IME	SOA based, ontology based, Federated simulation	Integrated multi-model analysis	Deterministic models
CISIA	population of nonlinear mutually dependent systems	High level modeling and simulation (macro-components)	Flexibility
CRESCO	CISIA/Federated ABMS Federated simulation	- Integrated environment for interdependencies analysis - High level and detailed simulation models	Flexibility
DIESIS	Ontology based/Federated Simulation	EISAC	N.A.
Federated ABMS	Agent-based/HLA based federated simulation	Probabilistic Interdependencies analysis	Flexibility
SimCIP	Federated Simulation/ propetary middleware	- Integrated environment for interdependencies analysis - High level and detailed simulation models	N.A.
Simphony	Repast (Agent-based)	Easy-to-use point-and-click environment for model building Easy-data analysis	Model re-engineering

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SimCIP	Federated Simulation/ propetary middleware	- Integrated environment for interdependencies analysis - High level and detailed simulation models	N.A.
DIESIS	Ontology based Federated Simulation / intelligent communication middleware	EISAC	N.A.

NISAC capabilities

- Dynamic Infrastructure Interdependencies Simulation & Analysis (DIISA)
- NISAC Agent-Based Laboratory for Economics (N-ABLE)
- Chemical Sector Analysis Capability
- Network Optimization Models (RNAS and ATOM)
- Advanced Modeling & Techniques Investigation (AMTI)
- Network Simulation Modeling Analysis Research Tools (N-SMART)
- Interdependent Energy Infrastructure Simulation System (IEISS)
- Water Infrastructure Simulation Environment (WISE)
- Urban Infrastructure Suite (UIS)
  - urban transportation, telecommunications, public health, energy (IEISS), financial (commodity markets), and water-distribution (WISE) infrastructures and their interdependencies.

What We can do for simulation (challenges)

- To study new methodology, techniques and tools for
  - data representation and analysis
  - knowledge/emergent behaviour discovery
  - simulation interoperability
    - Ontologies
    - Sensible data representation and exchange
  - integration of simulation models with DSS and optimization tools
  - output analysis
  - Economic models/policies to incentive stakeholders to share data

Conclusions

- Modeling and Simulation can do more for CIP ***iff***
  - Private/public sectors contribute providing data
  - Academia and R&D contribute to enanche M&S
  - Institution and Private sector help to develop expertice rather then to buy products

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ThankYou

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Slides available @
http://panzieri.dia.uniroma3.it/Colloquia/Colloquia24Marzo09.php