Panel on Computing Mechanisms Supporting Adaptability: Are There Missing Pieces in the Jigsaw?

Moderator: Dr. David J. Musliner
SIFT

Panelists

- Daniel Lafond, Thales Research and Technology, Canada
- Leslie Klieb, University of Liverpool, Laureate & Webster University Thailand, The Netherlands
- Kendall Nygard, North Dakota State University, USA
- Elena Troubitsyna, Abo Akademi University, Finland
- Dan Tamir, Texas State University, USA

Moderator’s Perspective

- Many technical challenges have already been tackled.
- Primary remaining challenges are non-technical:
  - Defining acceptable levels of (un)predictability for adaptive systems.
  - Establishing certification/licensing standards and frameworks that allow adaptive systems to be deployed in high-criticality applications.
- Key technical challenges support deployment: formal verification, testing approaches, certification.
- Societal challenges including legislation, legal status and liability issues, insurance.

Computer Mechanism Supporting Adaptivity

Dan Tamir

Texas State University
San Marcos, Texas

May 26, 2014

Dan Tamir, Associate Professor, Computer Science, Texas State University

- **Education:**
  - BS & MS-EE (BGU), PhD-CS (FSU)
- **Professional experience:**
  - Florida Tech, Motorola/Freescale, TX State
- **Areas of Interest:**
  - Incremental classification of Big Data
  - Disaster & Pandemic preparedness & mitigation via anomaly detection,
  - image processing,
  - usability

Dan Tamir, Associate Professor, Computer Science, Texas State University

- **Recent funding:**
  - Automating bridge inspection-feasibility study (TxDOT)
  - Power aware Task Scheduling (Semi-conductor Research Consortium)
  - Pinpointing of Software Usability Issues (Emerson – Process Control)
  - Laser lithography on non-flat surface (NSF)
  - Introducing parallel processing early in the curriculum (NSF)

Issues

- Low level image processing / recognition is still a challenging objective
  - Image segmentation
  - Image alignment
- Challenges include
  - Complexity
  - Scaling
  - Robustness
  - Perception concerning the complexity of the low level operation

- Numerous research tools placed in the pubic domain are not, mature, robust, sufficiently tested. Yet the are used “as is.”
- Supervised vs. non supervised leaning/implementation
- Evaluating the overhead and The uncertainty problem
- Ignoring the fact that adaptive systems might go out of control
- Simulation accuracy vs. speed

www.thalesgroup.com

Computing Mechanisms Supporting Adaptability: Are There Missing Pieces in the Jigsaw?

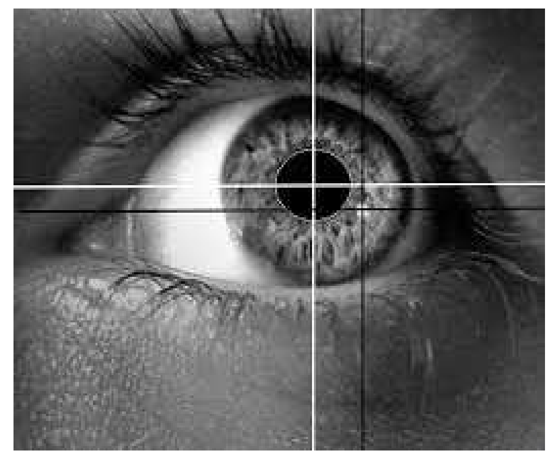
Daniel Lafond, *Thales Research and Technology Canada*

THALES

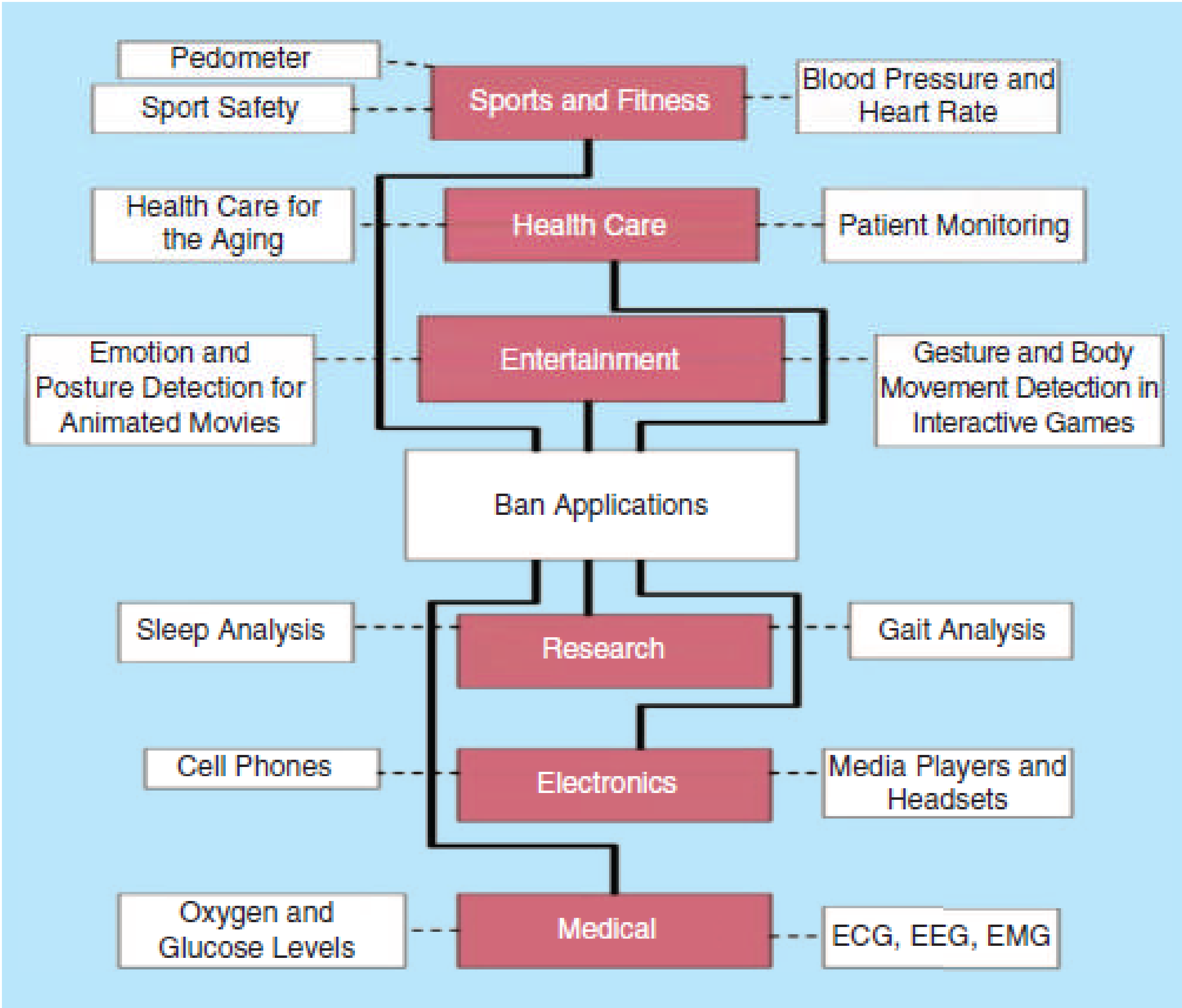
◆ Human-centric adaptability

Opportunities and challenges related to **human sensing** for creating the next generation of adaptive systems

A revolution in how we use sensors…



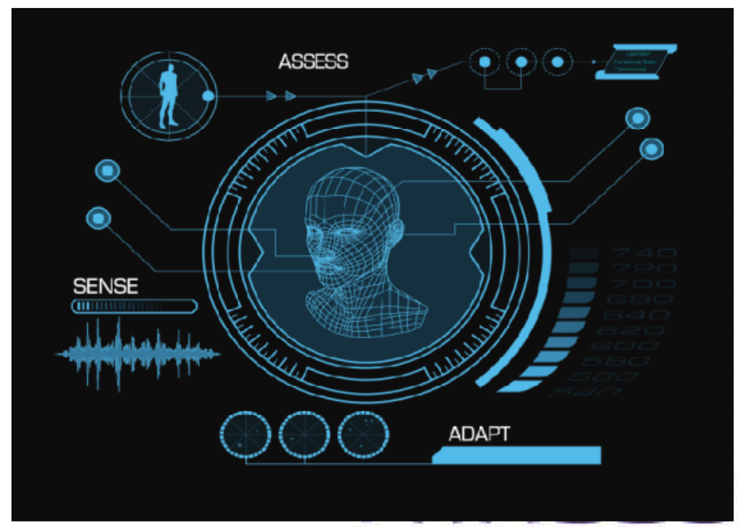
Explosion of “body area network” applications

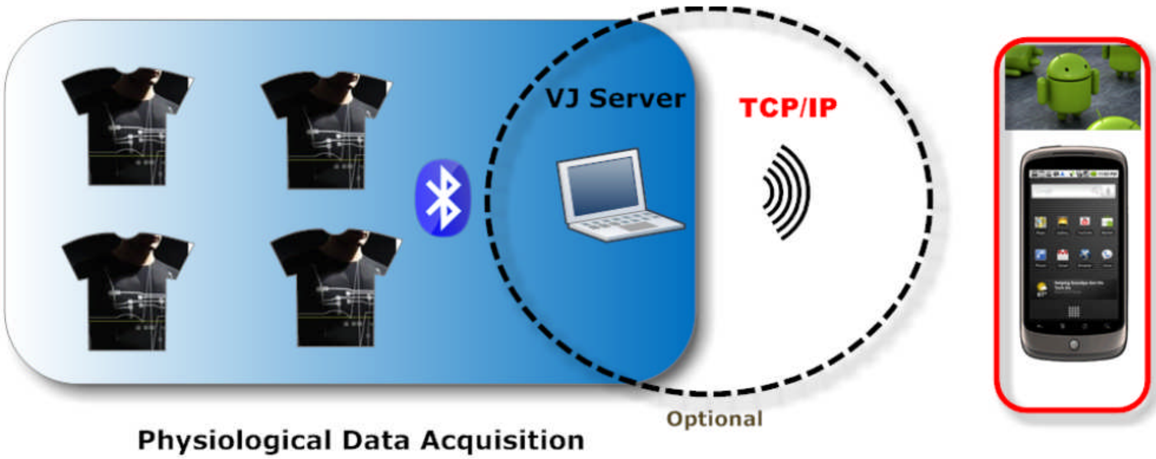


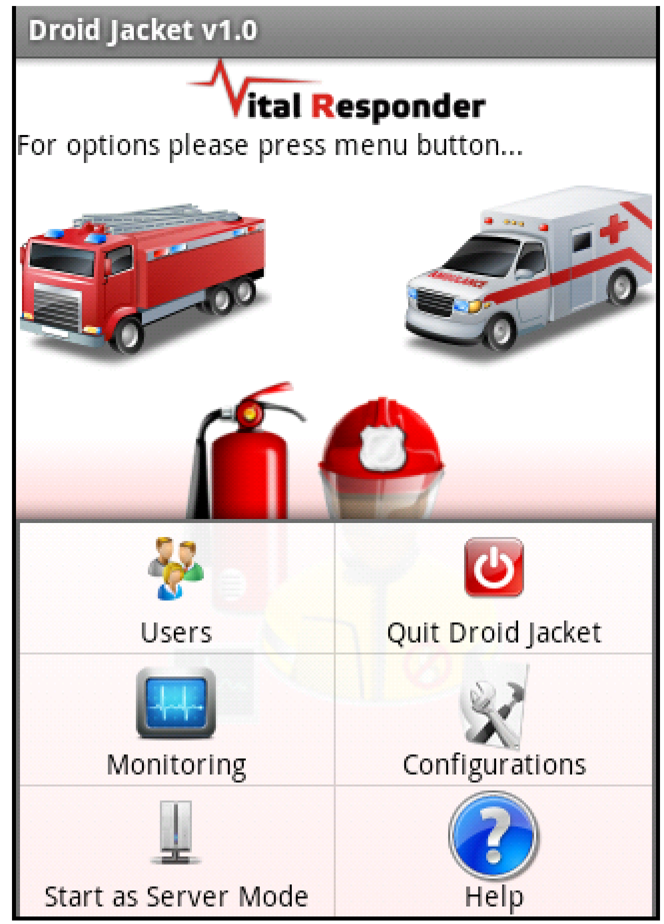
(Johny & Anpalagan, 2014)

Using psycho-physiological inputs to new support adaptive mechanisms…

- Cognitive counter-measures
- Adaptive automation
- Manning
- Safety protocols







Vital Jacket (Colunas et al., 2011)

➢ Key Adaptation Concepts for Complex Systems

- **Robustness:** Insensitive to perturbations
- **Flexibility:** Effective across a range of unanticipated situations
- **Resilience:** Cope with damage/loss while remaining functional (graceful degradation/fault tolerance)
- **Responsiveness:** Timely reaction to changes in the environment
- **Agility:** Ability to shift strategy/processes effectively

There clearly exist tradeoffs between these desirable properties that need to be better understood (Ryan, 2009)

Is there such a thing as being overly adaptive?

Adaptability challenge to dependability

Elena Troubitsyna
Åbo Akademi Univ.
Turku Finland

Adaptability challenge to dependability

- Current practice:
  Develop -> verify -> certify -> operate
- New trends: DevOps – no clear separation between development and operation of the system
  - continuous engineering
  - Learning user’s insight
  - Continuous extension of functionality
- How to ensure dependability?

Adaptability challenge to dependability

- Missing bits:
- Composition:
- How to avoid unforeseen and undesirable feature interactions
  - Dependability is typical not composition
  - Separation of concerns
  - Real-time issues
- Verification: development time activity
- How to transform into continuous verification?
  - How to extract verification conditions?
  - Run-time dependability monitors
- Current standards: the system should be recertified after each change
- Recertification – too expensive
- But no support from current standards
- Mixed-criticality systems

Adaptability challenge to dependability

- Variety of aspects -> variety of methods, models and tools
- How to ensure proper information flow between the tools?
  - Support for semantic binding

- Adaptation: blessing or curse for dependability?

Computing Mechanisms and Adaptability

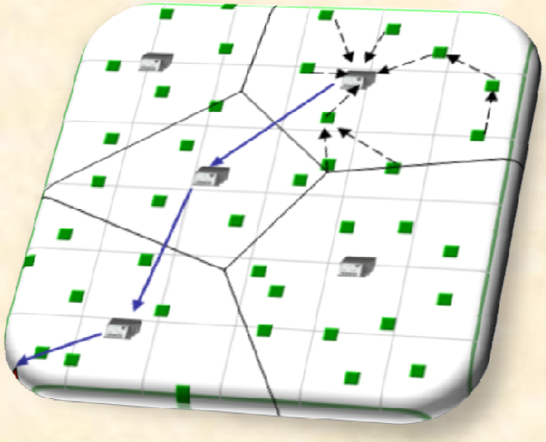
Kendall E. Nygard
North Dakota State University

Adaptive Systems with High Complexity

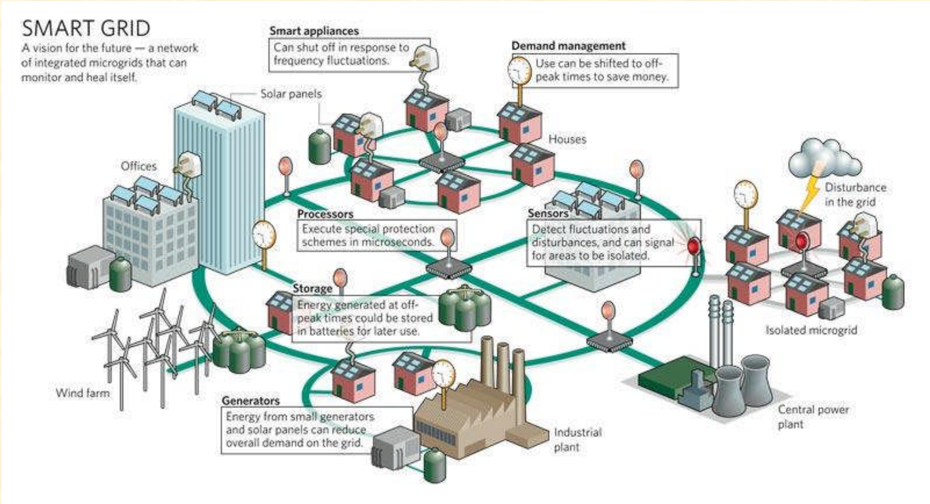
Unmanned Air Vehicles

Boeing

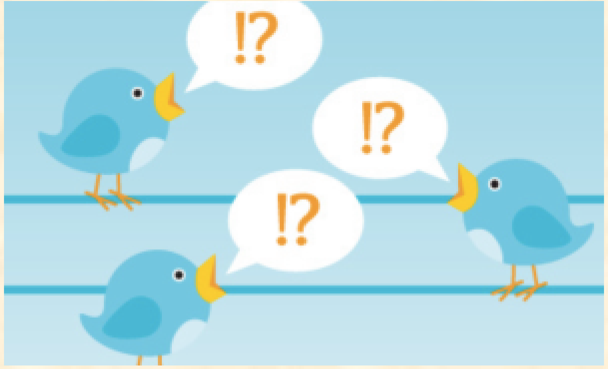
Sensor Networks



Smart Grid



Social Media Analytics



Typical Characteristics of Complex Adaptive Systems

- Many heterogeneous platforms
- Widely distributed, yet interconnected
- Support distributed Intelligent processing
- Must work together in purposeful ways

.

Reactiveness and Directedness

Reactiveness is achieved by a set of behaviors

Directedness is achieved by an intelligent capability that identifies and exploits structure, maintains a knowledge base, and accesses system knowledge to advantage

Distributed Decision Making

- Individual entities must be context-aware, yet combine dynamically to drive emergent and adaptive behaviors
- Embedded devices are at their best when they perform dedicated autonomous functions
- Little prospect for ‘top-down’ logic that would prescribe instructions for all elements
- Question: How robust and timely can distributed decision-making be?

Challenges for Adaptive Protocols and Algorithms

- Work is inherently distributed and bottom up
- Consensus building is difficult
- Data may be incomplete, limited, or unreliable
- Interaction topologies change dynamically
- Methods for achieving high reliability, security, and resilience are in the future

A Touch of Software Engineering and Software Architecture

- Code duplication across components
- Functional components may not be self-contained
  - Inherently decreases software quality
  - Makes reasoning at the architectural level difficult
- Cross-cutting issues
  - Context awareness
  - Culture and language
- Large-scale concurrency
- Massive non-functional requirements
  - privacy, security

Computing Mechanisms Supporting Adaptability: Are There Missing Pieces in the Jigsaw?

Leslie Klieb

Webster University Thailand, Univ. Liverpool/Laureate

Based on work with

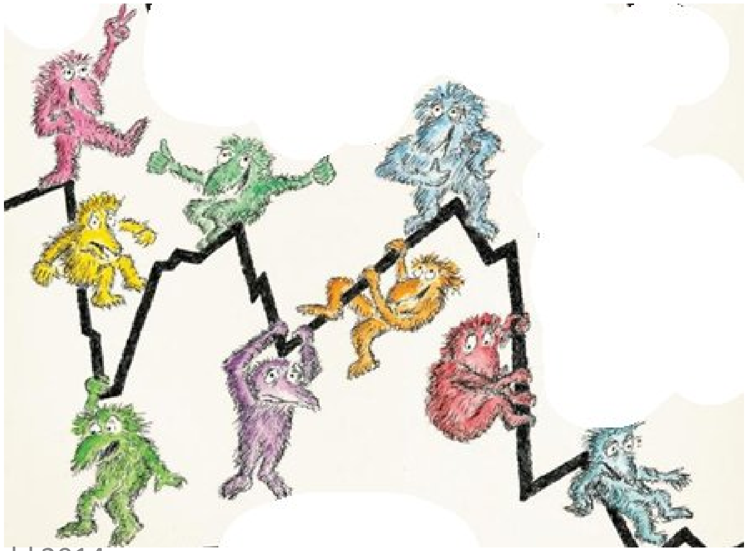
Merle Rhoades and Bill McKelvey

Panel ADAPTIVE / FUTURE COMPUTING / COMPUTATION TOOLS
COMPUTINGWORLD 2014 Venice Italy

- Computing Mechanisms Supporting Adaptability: Are There Missing Pieces in the Jigsaw?
- **Moderator** David Musliner, SIFT, LLC, USA
- **Panelists**
  - Daniel Lafond, Thales Research and Technology, Canada
  - Leslie Klieb, University of Liverpool, Laureate & Webster University Thailand, The Netherlands
  - Kendall Nygard, North Dakota State University, USA
  - Elena Troubitsyna, Abo Akademi University, Finland
  - Dan Tamir, Texas State University, USA

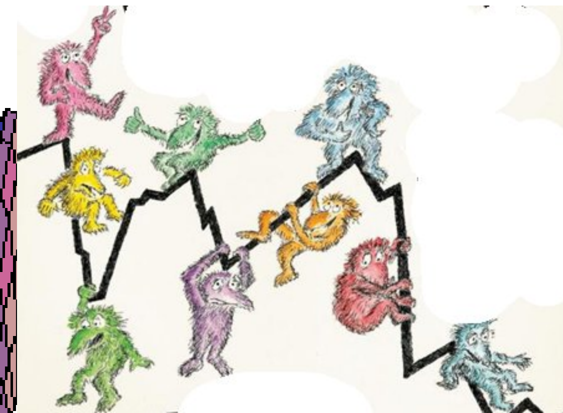
What are Complex Adaptive Systems?

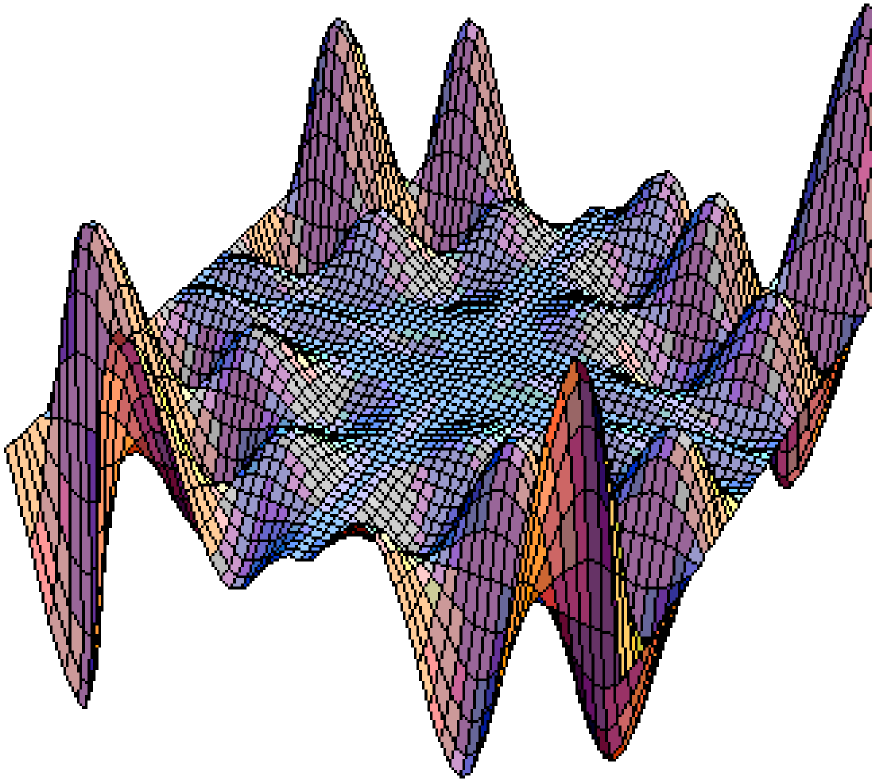
- Human Society, biological ecology, software systems consist of independent units: agents.
- Agents have interactions
- Dynamics comes from pursuing a perception of higher utility (fitness, cost function)
- Hallmark of CAS: dynamics irreducible



IARIA

Happy agents at the top, agents “hanging in” at the bottom





A fitness landscape

Why are realistic predictions about dynamics so difficult for a CAS?

- Not all reasons apply to all systems, of course!
  - Interactions (schemata) are insufficiently known and highly simplified
  - Agents misjudge other agents, they have incomplete information (wrong or misinterpreted information)
  - There are regions in phase space that have high sensitivity to initial conditions: chaotic regions

Why are realistic predictions about dynamics so difficult for a CAS? (2)

  - Phase space is highly-dimensional
  - CAS are far from (thermodynamic) equilibrium: there is a flow of energy and data going in and out.
  - Punctuated equilibrium (a dynamic equilibrium is prone to sudden disturbances)
  - Fractality: many overlapping systems (human agents are part of family, friends, work, neighborhood, …)
- Examples of unexpected events:
  - Disruptive technology
  - Biological evolution
  - Failures in large networks or in software systems with many unreliable components (instabilities in high-frequency flash trading on stock exchanges, large electric grids, …)

Possible approaches for remediation

- If the goal is:
  – understanding behavior and software simulation
    - Integrate out (=neglect) many dimensions in phase space.
    - Assign probabilities to various possibilities of each agent's behavior. Ensemble averaging/Monte Carlo.
    - Using small time scales for dynamics in chaotic regions might lead in some systems to fairly predictable trajectories before new influences from other agents lead to new trajectories. "Fuzzying out, pulling back"(feedback)

Possible approaches for remediation (2)

    - Forget worrying about exact dynamics, only care about to which “attractor” the system is going to converge (worry about which stable points exist).

- If the goal is:
  - Sufficient reliability of whole system, for instance software
    - Limit the behavior of each agent. That can only work if each agent has the larger good of the systems to which it belongs in mind (= programmed in its schemata). Can that be done?
      - Counter example: Rogue agents (malware, mistakes,…)
    - Stifles adaptability: biological evolution succeeded because the agents cared more about themselves or their close groups than about the stability of the whole ecosystem

This leaves us with some Big Questions about Simulation/Prediction

- Can we get sufficient understanding of complex adaptive systems for realistic predictions or reproduction of empirical data?
- How do you judge the quality of the simulation?
    - On one hand, results are probabilistic… [If Nate Silver predicts the outcome of the next presidential election wrongly – basically Monte Carlo - , was his model wrong or was it just a statistical fluke?]. Are models untestable?
    - On the other hand, results must be plausible. Many empirical "laws" like scale invariance should be reproduced. Serves as constraint

IARIA

Big Questions about system failure

- Is it possible to make an arbitrary complicated CAS-like system fault-tolerant? (Agent-level adaptability)
- Is it possible to make an arbitrary complicated CAS-like system adaptable to its environment? (System-level adaptability). Can software learn to defend itself?
- Is there a trade-off between the two?
- Is total system failure such a bad thing? Isn't it good that a system is sometimes beyond repair and a better system is going to occupy its ecological niche? Creative destruction?