DUNIP TECHNOLOGIES

Attention-focusing in Activity-based Intelligent Systems

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Outline

- Complex natural systems
    - Perspectives on Intelligent systems
    - RCIDS
- Emergent behavior
- Activity, Emergence and Systems theory
- Activity-based Intelligent systems
    - Event interoperability
- Activity, Context and Attention focusing
- Context Objectivity and Currencies
- Prototype model
- Summary

Complex Natural systems

- Self-similar/fractal
- Complexity at each hierarchical level
- Information boundaries at each level
- Information transformation across levels
- Information sensed, processed, synthesized and actuated within each level
  - "Relevant" information crosses these boundaries
- How can this relevance be engineered in artificial systems?
- System "just-is". There is no intelligence here!!

(Barbasi 1993, Pinker 1997, Mittal 2012)

RCIDS

Resource-constrained Complex Dynamical Intelligent systems

- Resource-constrained
  - Abstract notion of a limited resource (e.g. computational, energy, time, information, etc.)
- Complex
  - Presence of emergent behavior, irreducible to constituent components
- Dynamical
  - Temporal behavior, emergent response and stabilization periods
- Intelligent
  - The capacity of a system to process sensory input from the environment and act on the sensory input by processing the information to pursue a goal-oriented behavior.
- System
  - Conforms to Systems theory

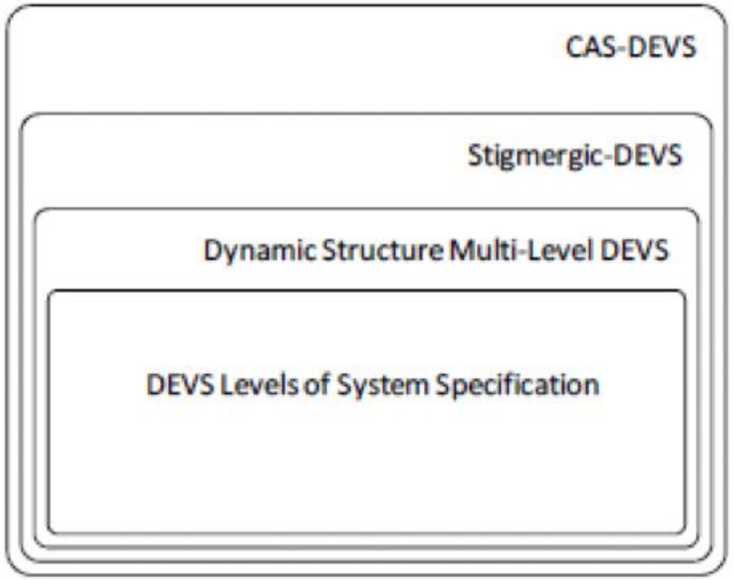
(Mittal and Zeigler 2014)

Types of Emergent behavior

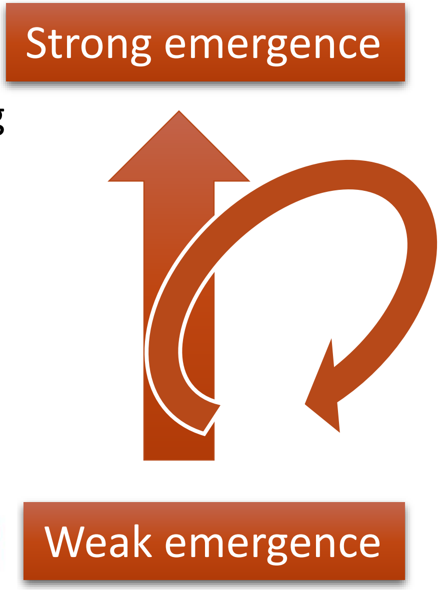
- Weak emergence
  - When emergent behavior can be reduced to a component behavior/interactions.
  - Systems that are designed using “closed under composition” principle can display repeatable weak emergent behavior.
  - It can be engineered as it is within a “closed” system
- Strong emergence
  - When emergent behavior is novel and cannot be reduced to a component.
  - It has causal nature at lower levels
  - It breaks information boundaries and a new nomenclature is required.
  - It makes a closed system an “open” system and make it a Complex Adaptive System (CAS)

(Bass 1994, Banabeau and Dessalles 1997, Deguet, et.al. 2006, Mittal 2012)

Activity, Emergence and Systems theory



Open System
- Scale-free topology and clustering
- Upward/downward causation
- Persistent environment



New information
- Knowledge
- Behavior
- Causation
- structures

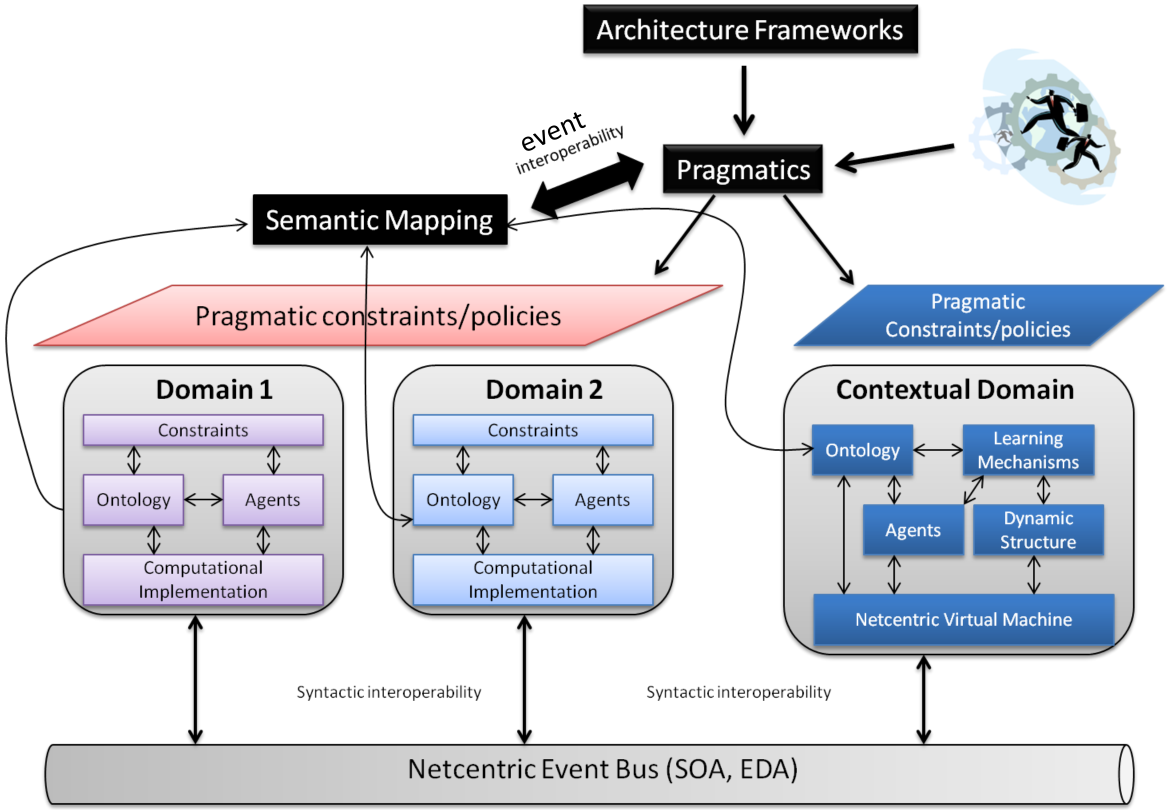
Closed system
- Closure under coupling

Activity measures, equivalence classes, distribution and correlation at Levels of Systems Specifications
- Level 2 : I/O Behavior trajectory level
- Level 3: State Transition level
- Level 4: Component level

(Mittal 2012, Zeigler 2012)

Activity-based Intelligent Systems

- Activity to be defined with “formal” events
- Activity characterization at multiple levels of interoperability
  - Event interoperability at pragmatic, semantic and syntactic levels
- *Emergent Streams* in a pragmatic frame
  - If validated at all the three levels then weak emergence
  - If invalid at semantic level, then Subject Matter Experts define new pragmatics and semantics, ensuring causality and refinement of systems’ behavior resulting in transformation of Strong emergent behavior to Weak emergent behavior (Open to Closed system)
- Event “transformation”
  - Event/Stream is a “model”.
  - A syntactic event may have different semantics in a different pragmatic frame
  - Notion of a contextual event



(Mittal and Martin, 2013)

Activity and Context

- Activity is an abstract concept and is multi-level and multi-resolutional
- Activity has dynamical behavior and is multi-faceted
  - Energy, Information, Context, etc.
- For intelligent goal-pursuing behavior, Activity needs to be partitioned on bottom-up and top-down phenomena
- At the gateway, Sampling managers and Rate Estimators are needed that define "Context"
  - Sampling Manager sample the **currency** (e.g. information, computational resources, time, energy, etc.) using different types of algorithms
  - Rate Estimator estimate the dynamical behavior of a gateway and provide a smoothing function to prevent rapid system oscillations (Activity has to persist "long enough")
- Semantic notion to Context
  - if pre-exists, it guarantees Weak Emergent behavior
  - Else results in Strong emergent behavior.
    - Once semantically tagged by SME and causality ensured, it reduced complexity by refining the systems behavior description

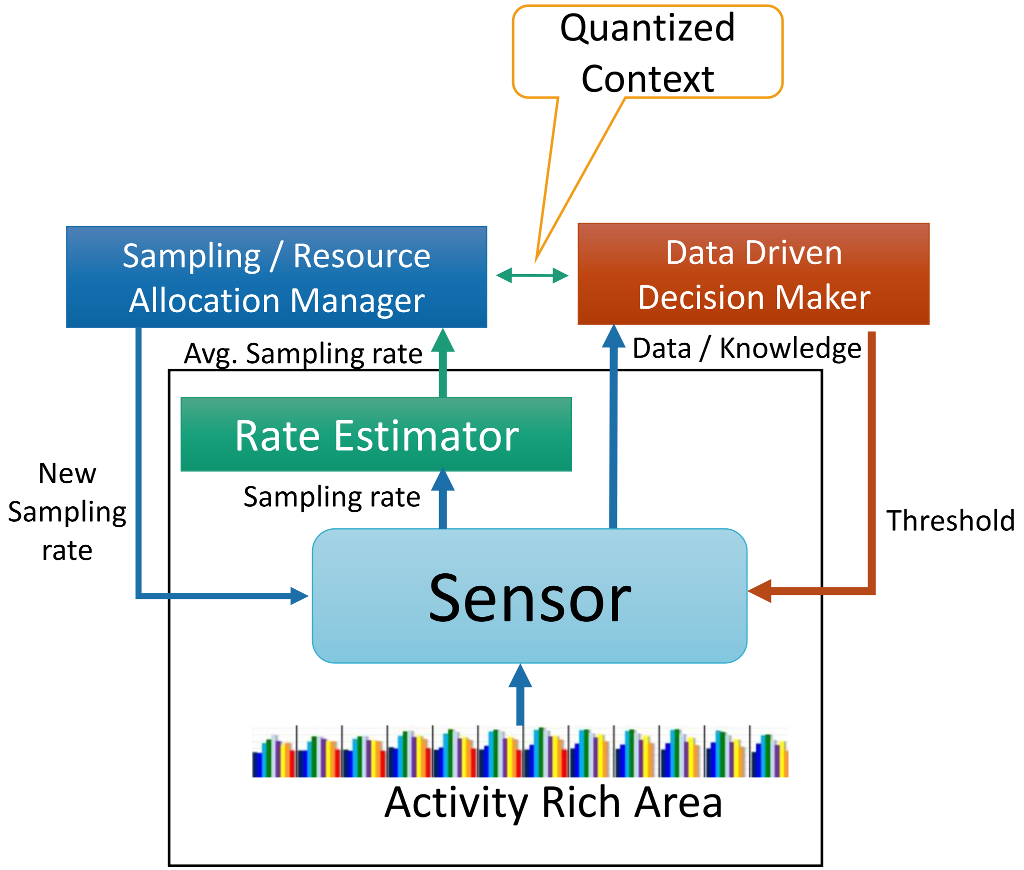
Activity and Attention-Focusing

- Context: The fundamental objective is of *Information Reduction*
- Attention: To attend in context
- Computational models of Attention
  - Saliency Map:
    - Winner Take All (WTA) on a set of Feature maps of stimuli linked to salient outcome and then inhibiting it.
  - Temporal Tagging
    - Neuronal activity binds all the active neurons/feature of an object in a temporal manner
  - **Emergent Attention**
    - **Neurons/Features engaged in competitive interactions and selection is the result of local interactions and top-down biases**
  - Selective Routing
    - Overlapping feed-forward and feed-backward neuronal paths

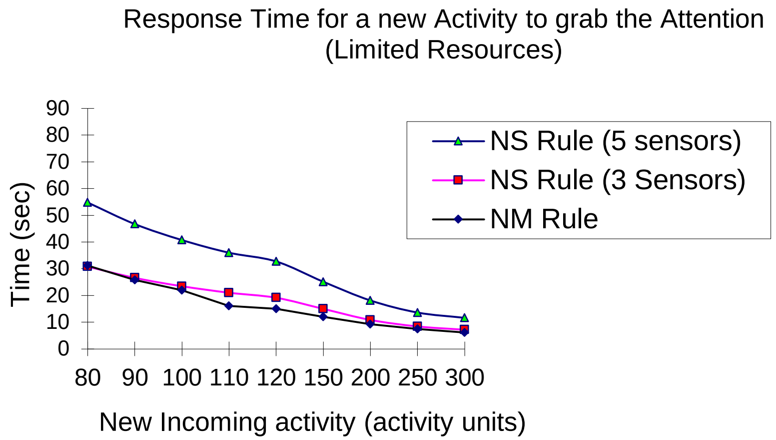
(Styles 1997, Shipps 2004, Tsotsos and Rothenstein 2011)

Context Objectivity in Artificial Systems

- Currency-agnostic Sampling Manager
  - Sets the sampling rate of Sensors
  - Currency determines Quantization
- Tunable sampling rate for dynamic resource allocation, thereby paying attention to the sensor (detecting Activity)
  - Goal: Threshold crossing model
- Algorithms inside Sampling Manager
  - Normalized Sum (NS) Rule
  - Normalized Max (NM) Rule
  - Tunable Alpha-Beta (TA) Rule



Sampling Algorithms



- Normalized Sum

$$S_k = \frac{A_k}{\sum_i^j A_i}.$$

$$where\ i < k \leq j; and\ i,j\ \subset N\ and\ j \geq 2$$

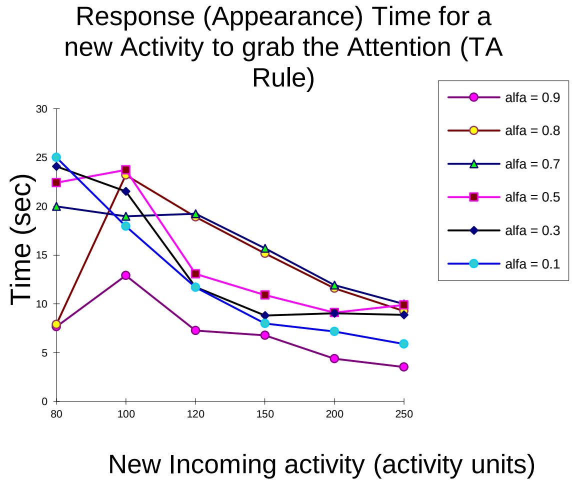
- Normalized Max

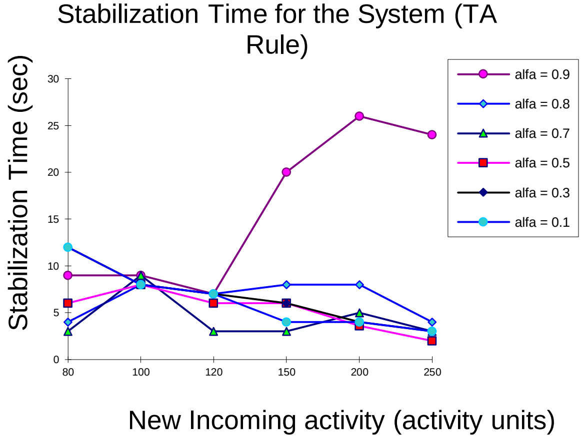
$$S_k = \frac{A_k}{A_{max}}$$

- Tunable Alpha-Beta

$$S'_k = \alpha S_k + \beta \frac{A_k}{A_{max}}$$

(Mittal and Zeigler 2014)





Summary

- Complex Natural Systems are self-similar and have multi-level emergent phenomena.
- RCIDS is a new class of intelligent systems with finite resources
  - Attention-switching is an emergent property of RCIDS
- Emergent behavior is classified into two broad categories, i.e. *weak* and *strong*, analogous to *closed* and *open* systems
- Activity has dynamical behavior and multi-faceted
  - To be partitioned for both bottom-up and top-down phenomena
- Emergent streams need to be detected, refined, contextualized and employed using Activity measures, equivalence classes and distributions
  - Emergent streams to be correlated with Systems theory

Summary … cont’d

- Event interoperability at syntactic, semantic and pragmatic levels
- Contextualization facilitates event transformation
- Quantized Context allows information reduction as event travels across multiple levels
  - Various types of Context currencies: information, time, energy, resources, etc.
- Sampling Managers and Rate estimators implement Context Quantization algorithms as influenced by top-down goals and bottom-up processing
- RCIDS prototype model demonstrated attention-switching with abstract activity measure and various sampling algorithms

Questions / Comments