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## **Complex Adaptive Systems: A Nominal Definition**

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### *Abstract*

Many writers and theoreticians have explored concepts and theories relating to complex adaptive systems. Complex adaptive systems concepts stem from seminal contributions by Jantsch, Prigogine and Stengers, Maturana and Varela, Gell-Mann, and Holland. To date, however, no one has bothered to create a nominal definition to define what a complex adaptive system is. This paper presents a concise definition that serves that purpose.

### *Introduction*

The complexity paradigm uses systemic inquiry to build fuzzy, multivalent, multi-level and multi-disciplinary representations of reality. Systems can be understood by looking for patterns within their complexity, patterns that describe potential evolutions of the system. Descriptions are indeterminate and complimentary, and observer dependent. Systems transition naturally between equilibrium points through environmental adaptation and self-organization; control and order is emergent rather than predetermined (Dooley, et al. 1995; Lewin, 1992; Waldrop, 1992).

The complexity paradigm is operationalized by the concept of a complex adaptive system (CAS). Examples of a CAS include economies, ecologies, weather, traffic, social organizations, and cultures, to name but a few (Gell-Mann, 1994). There is a myriad of writings concerning how a CAS behaves, how it is structured, and how it evolves. While many writers and researchers have studied CAS, a concise nominal definition does not exist.

### *Method*

The nominal definition to be put forth is forged from the works of Gell-Mann (1994), Holland (1995), Jantsch (1980), Maturana and Varela (1992), and Prigogine and Stengers (1984). The essential principles of a CAS, as defined in each work, were carefully noted. These conceptual lists were then merged into one master list of concepts. Common themes were noted and an abbreviated list was developed. This aggregate list of concepts was then put into a structural model that synthesized the concepts into a single description.

### *Nominal Definition*

The basic elements of a CAS are agents. Agents are semi-autonomous units that seek to maximize their fitness by evolving over time. Agents scan their environment and develop schema. Schema are mental templates that define how reality is interpreted and what are appropriate response for a given stimuli. These schema are often evolved from smaller, more basic schema. These schema are rational bounded: they are potentially indeterminate because of incomplete and/or biased information; and they differ across agents. Within an agent, schema exist in multitudes and compete for survival via a selection-enactment-retention process.

When an observation does not match what is expected, an agents can take action in order to adapt the observation to fit an existing schema. An agent can also purposefully alter schema in order to better fit the observation. Schema can change through random or purposeful mutation, and/or combination with other schema. When schema change it generally has the effect of making the agent more robust (it can perform in light of increasing variation or variety), more reliable (it can perform more predictably), or more capable in terms of its requisite variety (in can adapt to a wider range of conditions).

The fitness of the agent is a complex aggregate of many factors, both local and global. Unfit agents are more likely to instigate schema change. Optimization of local fitness allows differentiation and novelty/diversity; global optimization of fitness enhances the CAS coherence as a system and induces long term memory.

Schema define how a given agent interacts with other agents surrounding it. Actions between agents involve the exchange of information and/or resources. These flows may be nonlinear. Information and resources can undergo multiplier effects based on the nature of interconnectedness in the system. Agent tags help identify what other agents are capable of transaction with a given agent; tags also facilitate the formation of aggregates, or meta-agents. Meta-agents help distribute and decentralize functionality, allowing diversity to thrive and specialization to occur. Agents or meta-agents also exist outside the boundaries of the CAS, and schema also determine the rules of interaction concerning how information and resources flow externally.

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