"A good read and a re-read."

For more than a century, some have suggested we treat a human organization like an organism - treat human society like a machine - apply the terms and concepts of rule-bound activity systems (as in cybernetics and system dynamics) to human sociology. Yes, we do have rule-bound games and business systems. Activity systems thinking is relevant and useful. Beyond that, we need social entity thinking as well.

Consider for example a game of poker.

- The rules of poker are an abstract activity system, which represents
- a poker game in progress, which is a physical activity system, realized by
- actors playing roles in a card school, which is a social entity.

Some regards an enterprise as a "system of systems". This article regards an enterprise as a social entity that can realize any number of (possibly conflicting) activity systems. Read on for discussion of what that means. Then, for the application of particular systems thinking ideas to enterprise architecture (EA), read **article 2** and the associated slide show.

PREFACE

A system is a pattern, meaning there is some describable regularity or repetition, some orderliness, in its structure and/or behavior. General system theorists look to identify concepts, patterns and principles that are common to systems as they are discussed in different sciences.

In practice, some system thinkers generalize the meaning of terms to the point of vacuity, and some use what appear to be common terms in different, domain-specific ways, which lead to cross-domain misunderstandings.

Beware over-generalization

Some lean on definitions that are readily believable, and sound profound, but turn out when exemplified to be so generalized they are of little help in practice. For example:

- *Systems thinking* is a way of thinking about selected aspects of the world and their interrelationships which is useful in relation to the individual's concerns.
- A *system* is a thing contained or connected in some coherent way.
- An *adaptive* system is disposed to act or change in response to external events or internal conditions.
- A *complex* system doesn't behave in a simple linear way (cause A to effect B).

The trouble is that:

- *every* way of thinking is about selected aspects of about the world, and relates them to each other and/or the concerns of the thinker.

- *everything* from an atom to a solar system is contained or connected in some sense, and is disposed to act or change in response to external events or internal conditions.
- *simple* structures (especially ones with feedback loops) can behave in ways describable as non-linear, unpredictable, even chaotic.

If everything you can think of is a system, everything changes over time, and simple things meet the definition of complex things, then how to differentiate systems thinking from thinking? And what useful meaning does the term "complex adaptive system" convey? (More on CAS later.)

To be useful, rather than generalizing to the point of vacuity, one has to be more particular.

Beware ambiguities

This article identifies and distinguishes some concepts particular to system thinking. In doing so, it exposes and explores ambiguities in the terminology of systems thinking. For example:

- “Adapting” can mean changing the state of a thing and/or changing it into a different thing.
- “Agency” can mean the ability or freedom of an actor to choose between actions in a role, or the ability to invent new actions (possibly in conflict with the aims of a system the actor plays a role in).
- “Complex” can mean messy/disorderly, or the opposite, a measure of orderliness. It can refer to the complexity of a structure or of a behavior.
- “Emergent properties” can relate to the evolution of the universe, or the simple idea that interactions produce results individual entities cannot produce alone.
- “Fractal” is abused to mean composable and decomposable.
- “Holism” is abused to mean wholeism - which is impossible, since we can never study all that could be known about a thing, we can only (and must necessarily) select the aspects of that thing that are relevant to our interest in it.
- “Non-linear” is used by people with various meanings, and no meaning.
- “Reductionist” and “linear” are used as insults (perhaps by those who don’t know how general system theory addresses non-linear behavior in complex, adaptive systems).
- “Self-organizing” (Ashby said) perpetuates a confused way of looking at systems.
- “Systemic” is often used to mean everything - rather than throughout.

As if natural language ambiguities were not enough, misunderstandings also arise when systems thinkers speak metaphorically (use words figuratively) or say one thing is isomorphic with another thing (has the same structure). So, the words they use may not mean what you think; and drawing an analogy between things with the same structure does not mean they behave in the same way, or should be treated in the same way.

This article explores and explains two kinds of structure (passive and active), two kinds of whole (structural and behavioral), two kinds of emergence (from evolution and from interaction), two kinds of social system (actor centric and activity centric), two kinds of state (physical and conceptual), two kinds of behavior (process and state change), two kinds of process (deterministic and stochastic), two kinds of system (abstract and concrete), two kinds of freedom (to select and to invent), two kinds of purpose (intent and outcome), two kinds of organization (order in general and social structure in particular), two kinds of change or adaptation (state change and mutation), and two kinds of mutation (designed and accidental).

Before we address those dichotomies let us start with some simple ideas used in modelling business activity systems.

Some simple system concepts

This article draws on analysis of Ashby's "Introduction to Cybernetics", Ackoff's "Towards a system of system concepts" and many modern sources.

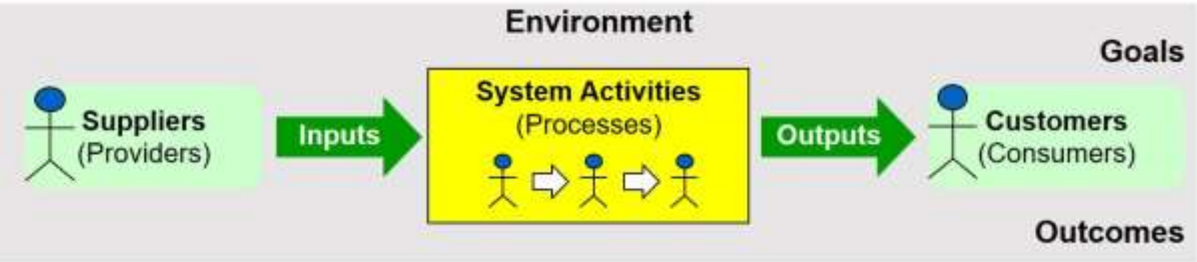
Russell Ackoff was known as a brilliant observer of humans, their institutions and their failings. He was also known as a systems thinker. In "Towards a System of Systems Concepts" (1971) he started some distance from human society, with more general ideas about the state of a system and of its environment. Here are some of them.

- A system has an internal **state.** The current state can be represented by the current values of descriptive state variables.(eg. temperature, volume)..
- A system is bounded, and can be closed or open. An **open** system interacts with its environment by consuming **inputs** and producing **outputs.**

Ackoff devised a four-way classification (discussed later) that embraced human organizations as systems of the kind above. This article proposes we do better to contrast social entities and activity systems. Before we consider Ackoff's classification and that proposal, let us begin with simple some ideas about business activity systems.

The external architecture of a business system

Traditionally (for example, in Checkland's "soft systems methodology") a business system is modelled as a set of regular activities that transform inputs into outputs. The diagram below encapsulates the processes of an activity system and connects it to actors in its environment. The requirements for a business system are usually found outside the system.



The processes of the system are bounded within a wider environment. What this SIPOC diagram doesn't show is that the outputs of a business system (say invoices) can influence its future inputs (say, payments). In other words, there are feedback loops between a business system and actors in its environment.

A few core business system modelling concepts are listed below.

- **System** = a bounded set of regular activities performed by actors playing given roles.
- **Input** = an information or material product consumed by a system, supplied by some external actor(s)
- **Output** = an information or material product provided by a system to some external actor(s)
- **External actor** = a player of customer, supplier, user or observer roles.
- **Outcome** = an actual effect of outputs being used by external actors.
- **Goal/objective** = a desired effect of outputs being used by external actors.

The internal architecture of a business system

Having encapsulated an activity system as shown above, you may go on to encapsulate each subsystem or component inside it. You can decompose the system into subsystems that interact with each other. Then decompose each subsystem, and so on, until you reach what you regard as atomic actors and activities.

System decomposition is a simple idea; it is important and useful today. However, there are many other ways of looking at systems. And when studying systems thinking one has to be wary of many ambiguous terms.

SOME AMBIGUITIES

Two kinds of structure (passive and active)

- "Rather than reducing an entity to the properties of its parts or elements, systems theory focuses on the arrangement of and relations between the parts which connect them into a whole. This particular organization determines a system" Principia Cybernetica Web

What does "organization" mean? One naive interpretation is that it refers to a structure in which the parts of a whole are connected. Structures can be classified in many ways, and we should start by distinguishing active structures from passive ones.

Passive structures

Is every entity divisible into related parts a system? A garden fence and a pack of cards are structures composed of related parts; but they are passive rather than active. The chemists' periodic table of elements is another passive structure; it is a pattern, it is interesting, and some may call it a system, but it is not a system of interest in the sense here.

https://www.sciencekids.co.nz/pictures/chemistry/periodictable.html

Active structures

Active structures are actors who can not only connect in some way, but also interact to advance the state of a system. The systems of interest to us include active structures, and may be seen as active structures themselves. Think of:

- a solar system in which orbiting planets interact by gravity with a star and each other
- a windmill in which parts rotate and interact to grind corn and make flour.
- a tree in which parts interact to consume sunlight and carbon dioxide, and produce a tree trunk and oxygen.
- a boxing match in which boxers and a referee interact to advance the state of the match, as recorded on the judges' scorecards.

Bear in mind the passive/active distinction is a matter of perspective.

A sandstone pebble is an entity composed of sand or quartz grains connected by cement. It is a discrete entity - created, changed and destroyed by events. We normally see it as a passive structure.- as acted on rather than an actor. However, it can be recast as an active structure; it can be presented as dynamic system that absorbs and excretes a small amount of water.

Narrative and mathematical descriptions are passive structures. However, some descriptions can be animated. Human and computer actors not only read descriptions of activities to be performed, but also perform those activities.

Two kinds of whole (structural and behavioral)

The first general system theorist, the biologist Ludwig von Bertalanffy, wrote

- “General System Theory… is a general science of wholeness".

Some define a system along these lines “A whole made of related parts that are ordered in some way.” The concept of a whole can be seen from two perspectives.

Whole as a structure - a set of connected parts

The study of whole-part relationships is called mereology. Mereological discussions typically refer to a physical thing - like a chair or an organism - as a structure composed of inter-connected parts. Mereologists have to address the questions below.

- *What is the scope of the whole?* Bertalanffy had studied biology. Bounding an organism is easy. You can see or touch the boundary of the organism - its skin. By contrast, how to determine the scope of the solar system, a bank, or a legal system?
- *What counts as a part?* You naturally see everything inside the skin of an organism as a part of that whole. By contrast, how to determine which actors belong to a social entity? Every member of a family, tribe or species? Every actor within a geographical area? Every actor connected by physical contact to other

actors? Every actor connected by communication in a "community". Or every actor with a membership number?

- *Can one part be a member of several wholes?* Can those wholes be in conflict with each other? Can parts have degrees of membership from loose to strong?
- *In what sense does a whole "contain" its parts?* You body contains organs and cells that have no role outside of your body. But a game of poker does not contain card players - who have lives outside of playing cards. They play roles in countless other systems. And even while playing cards their minds may stray to their roles in unrelated systems.

A system thinker has proposed "by understanding its structure, we can understand the states a system will exhibit." To the contrary however, for example, the organization chart of a business does not explain the processes it performs or their results.

Mereology is insufficient as a basis for understanding and explaining the activity systems of interest to us. Focusing on structures leads some to confuse a physical entity with the activity systems it may realize, and/or confuse actors with roles they play in different systems.

Whole as a behavior - a set of interactions

How actors connect in a structure is one thing, how actors interact is another.

Find and watch a video of a "double pendulum". Its structure is very simple - just two components - connected at one point. Understanding its structure does not help you predict its behavior or the states it will exhibit. The double pendulum looks to be a very simple machine, yet it displays what some might call "complex" or "chaotic" behavior.

Holism not = wholeism. We can never describe the whole of something. We can only describe our narrow perspective of any reality we observe.

- "Our first impulse is to point at [some physical thing] and say "the system is that thing there". Any suggestion we study all the facts is unrealistic [in practice we] pick out and study the facts relevant to some main interest already given.... there can be no such thing as the unique behaviour of a very large system... for there can legitimately be as many [systems] as observers" Ashby 1956.

Holism does *not* mean understanding everything about a whole. It means understanding how selected parts interact to produce some emergent properties of interest. For example, a causal loop diagram of a biological ecology *excludes* almost everything knowable about the physical reality it models.

The narrower your selection of parts, the less you know of other parts. The bigger the parts you select, the less you know of what they contain.

- "Were the engineer to treat bridge building by a consideration of every atom he would find the task impossible by its very size [therefore] studying very large systems by studying only carefully selected aspects of them is simply what is always done" Ashby 1956.

Two kinds of emergence (from evolution and from interaction)

Some systems thinkers see "emergence" as the concept most definitive of systems thinking. Even this term is used in two different ways.

- The historical emergence through evolution of higher level phenomena (e.g. psychological) from lower level (e.g. biological)
- The everyday emergence of novel effects from interactions between things.

The emergence of complexity in the evolution of the universe

Bertalanffy presented hierarchical "organicism" as a core idea in his general system theory.

- “We presently "see" the universe as a tremendous hierarchy, from elementary particles to atomic nuclei… to cells, organisms and beyond to supra-individual organizations.” Bertalanffy 1968

This idea is widespread outside of systems thinking.

- "Today, it’s a real intellectual deprivation to be blind to the marvellous vision offered by Darwinism and by modern cosmology – the chain of **emergent complexity** leading from a ‘big bang’ to stars, planets, biospheres, and human brains able to ponder the wonder and the mystery of it all." Quoted from this essay on science.

Gustavo Romero wrote that reality seems to be organized into.at least 6 levels.

- "In order of **increasing complexity**: 1 ontological substratum [basic events]; 2 physical [material]; 3 chemical; 4 biological; 5 social; 6 technical." From “On the ontology of space-time”

Romero's level 1 "is formed by basic events and precedes the emergence of physical things at the physical level." This reflects the presumption that events come before entities. Every entity in the universe is created, changed and destroyed by events. What we perceive as persistent structures are the transient side effects of behaviors. An entity can be modified by events in ways that change its state (e.g. cold to hot), or change its type or the activities it can perform (e.g. caterpillar to butterfly).

Levels 2 to 5 each contain a collection of entities and events that share certain properties and are subject to certain laws. At level 2, matter and energy obey the laws of physics. At level 3, molecules interact according to the laws of chemistry. At level 4, animals embody biological processes. At level 5, human behavior requires interactions between - chemicals at the chemical level - synapses at the biological level - perceptions and memories at the psychological level - people at the social level. Each step up to a higher level adds some emergent properties and laws - adds complexity you may say.

Level 6 is oddly placed in terms of complexity. Consider a pendulum; this very simple technology is a physical system that operates at level 1. The fact that it was designed by a person does not make it more complex than a person or a society.

For the purposes of this article, the table below adapts and extends Romero's levels.

THINKING LEVEL	Elements or actors	Interact by	Knowledge acquisition
Physics	Material things	Forces	
Inorganic chemistry	Molecules	Chemical reactions	
Organic chemistry	Carbon-based molecules	Chemical reactions	
Biology	Living organisms	Sense, response. Reproduction	Inheritance
Psychology	Animals with memories	Sense, thought, response	Conditioning
Social psychology	Animals in groups	Information encoded in signals	Parenting and copying
Human sociology	Humans in groups	Information encoded in speech	Teaching and logic
Human civilization	Human organizations	Information encoded in writings	Schooling and legislation

It seems reasonable to say that complexity (in the orderly rather than messy sense) increases or emerges when moving from a lower level of thinking to a higher level.

- Chemical evolution after the big bang complexified the periodic table and the range of possible chemical reactions.
- Biological evolution might be described as a process that tends to complexify the organisms of a species, and widen the range of an animal's possible behaviors.
- Human evolution has created actors who can envision and produce new things (e.g. paintings), new activities (e.g. card games), new tools and new software systems. .

Bear in mind that the complexity of a thing is a matter of perspective.

- The solar system, as modelled in an orrery, is simple. When thinking about the orbits of planets, we ignore the substance and surface of each planet, and life on earth.
- A game of poker is a simple social system. The rules of the game say nothing about the psychology or biology of the card players; those are taken for granted.

The everyday emergence of effects from interactions between entities

A different kind of emergence may be seen. At any level of thinking, you might identify a system in which parts interact in regular activities. Emergence occurs when an interaction between parts produces an effect or result that no part can produce on its own. Consider the effects or results that emerge from interacting things in these examples:

- the progress of a rider on a bicycle
- the force produced by a wind passing over a sail
- the V shape of three geese in flight

- the shimmering of a school of fish
- the price of fish that emerges when customers and suppliers strike a deal

Contrary to what you may read elsewhere, emergence does *not* require a system to have many actors, to behave in a surprising or unpredictable way, or to be complex in any normal sense of the term.

True, natural systems often produce results or effects that appear surprising or mysterious. By contrast, designed systems are intentionally designed to produce specified results or effects.

Given a business system to design, the designer must start with the desired effects of the whole. And when a designed system produces unexpected effects, we call them "unintended consequences".

Four kinds of causality

Causality (or cause-to-effect processes) might be classified into four kinds. Here, you may read "input" as being an event or a condition.

1. **Deterministic** means that given input A and current state B, the next action is C.
2. **Probablistic** means that given input A and current state B, the next action is C (probability X) or D (probability Y).
3. **Possibilistic** means that given input A and current state B, the next action is C or D, with no measurable probabilities attached to those options.
4. **Innovative** means that given input A, an intelligent actor/agent invents a new action, outside of any range that has been considered or modelled so far.

Activity systems thinking (as in cybernetics) addresses 1, 2 and 3. It models a system as a holistic network of activities that can be sequenced in processes of those kinds.

Sociology may addresses all four kinds. Whether our psychology is deterministic or not at the biological level is irrelevant. At the sociological level, we have no option but to treat people of sound mind as having free will. So, where the actors in a system are anthropomorphic rather than computational, we assume they can not only choose between options (3) but also be innovative (4).

E.g. in a poker game, the range of possible actions is limited to those that characterize the system. The rules do not tell players whether to "call", "raise" or "fold". Players strive to make their choices unpredictable. They also try to detect probabilities in how others choose between the possible, allowable, actions. Outside of their role in playing cards, the same human actors are innovative; they invent new responses to events and conditions.

Where actors do invent actions, a social entity is not well called a system. So, might a CAS with human actors better be called a complex adaptive social entity (CASE)?

Two kinds of social system (actor centric and activity centric)

In an article on general system theory as the skeleton of science (volume 2 of the journal "Management Science", 1956) Kenneth Boulding referred to the question of whether the elements of a social system are actors, or the roles they play in activities. The question goes all the way back to the origins of sociology in the 19th century.

- "The first decision [a theoretician has to make] is what to treat as the basic elements of the social system. The sociological tradition suggests two alternatives: either persons or actions." Seidl 2001

In other words, given that **actors** are active structures (organisms, organs, people, technologies computers, software components) that occupy some space, and **activities** are behaviors performed by actors over time, two branches of social systems thinking may be distinguished.

- In actor-centric **social entity thinking**, there is a network of actors, who determine the activities they perform. (The activities are changeable.)
- In activity-centric **activity system thinking**, there is a network of regular activities, in which actors are defined by their roles. (The actors are changeable, and may act outside the system.)

Other views are possible (e.g. aim-centric and state variable-centric) but the dichotomy above is the best explanation of why so much systems thinking discussion is confused or confusing.

How enterprise architecture applies these ideas

For the application of these ideas to EA, read **article 2** and the associated slide show. In short:.

- EA starts from the aims of system sponsors and other stakeholders, and identifies the desired outcomes, products and services, that currently or should emerge from business activity.
- EA sees a business as a holistic network of activities, which are sequenced in deterministic, probablistic and possibilistic processes (or value streams).
- EA is largely not about the design of physical structures (buildings, hardware, vehicles and human bodies) but it does assign activities to logical structures - functions and roles.
- EA is about business roles and processes in which active structures - human and computer - create and use passive data structures to store and convey information..
- EA requires also some social entity thinking. Logical functions and roles are mapped to physical organization units and actors.

This article further discusses the general concepts and principles of both activity systems thinking and social entity thinking. For their application to EA, read article 2.

ACTIVITY SYSTEMS THINKING

Chapter one of Meadows' primer for systems thinking starts thus:

- “A system isn’t just any old collection of things." [It is a] "set of elements or parts that is coherently organized and interconnected in a pattern or structure that produces a characteristic set of behaviors.".

A business activity system may reasonably be defined as a set of actors and resources that is coherently organized and interconnected so as to perform required activities. It is orderly; it is dynamic; and characterized by the regular activities performed by actors.

- A system has an internal **state.** The current state of things can be remembered in the values of state variables and communicated in messages..
- A system is bounded, and can be closed or open. An **open** system interacts with its environment by consuming **inputs** and producing **outputs.** The outputs change the state of things in the environment of the system.
- A system's structural elements or actors play roles in activities. **Actors** are active structures that occupy some space. **Activities** are regular behaviors performed over time by actors, which advance the internal state of the system.

Systems of a similar kind can be found in many sciences. There are physical activity systems (e.g. a steam engine), biological activity systems (e.g. a human heart) and social activity systems (e.g. a poker game). This table sketches out some other examples.

Domain	System	Actors (active structures)	Activities (behaviors)	State (facts of interest)
Physics	A solar system	Start and planets	Orbits	Planet positions
Physics	A windmill	Sails, shafts, cogs, millstones	Rotations transform wind energy and corn into flour	Wind speed, corn and flour quantities
Biology	A digestive system	Teeth, intestines, liver, etc.	Transformation of food into nutrients and waste	Nutrient and waste quantities
Biology	A termite nest	Termites	Disperse pheromone. deposit material at pheromone peaks	The structure of the nest
Ecology	A prey-predator system	Wolves and sheep	Births, deaths and predations	Wolf and sheep populations
Human sociology	A tennis match	Tennis players	Ball and player motions	Game, set and match scores
Human sociology	A church	People	Roles in the church's organization and services	Various attributes of roles and services
Human civilization	A software system	Computer	Calculate perimeter, area, etc.	Radius, the value of pi (invariant)
Human civilization	A billing system	Customer and supplier	Order, invoice, payment	Product, unit price, order amount

Two kinds of state (physical and conceptual)

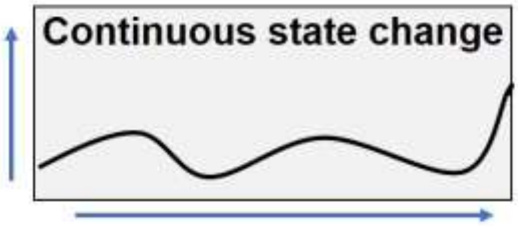
The passage of time is revealed by changes. The universe is an ongoing process in which the state of things changes over time.

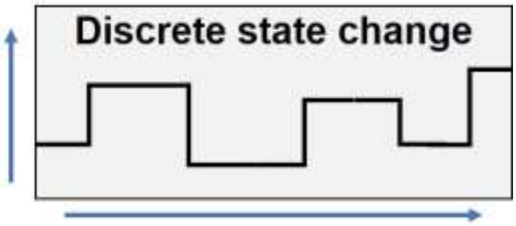
E.g. Consider a tennis match. At any moment in time, the players, the balls and the tennis court have a current material or physical state, which we don't attempt to measure. At the same time, the tennis match has the conceptual state shown on the score board.

In practice, we represent the physical state of a thing as a conceptual state, as a **vector** containing the values of **state variables**.

E.g. In physics, the vector of an object might contain its spatial coordinates at a moment in time. And in economics, the vector might contain the current inflation rate and unemployment rate.

A graph can be drawn to show the trajectory of change to a state variable's value over time, be it continuous or discrete.





If the vector has only two or three numerical variables, its value at any time can be represented as a point on a two or three-dimensional graph. And the trajectory of the vector over time can be shown visually as two or three-dimensional shape.

[Examples would be nice here.]

Systems thinking is concerned with things whose state vector changes over time. Some things advance continually from one state to the next. E.g. a moon rocket, or a tennis match. Some things cyclically return to the same point, or stabilize themselves in an equilibrial state. E.g. a solar system, or a thermostat-controlled room temperature

An **attractor** is a vector value towards which a system is drawn (for a variety of starting conditions). Systems with a vector close to an attractor tend to remain close it, even if slightly disturbed. The attractor can be a point, a line, a curve, or a multi-dimensional manifold. It can even be a set with a fractal structure - known as a *strange attractor*.

Two kinds of behavior (process and state change)

For some, a behavior is a process - any action, activity, operation or procedure that takes time to perform - perhaps as shown in some kind of flow chart. That is the usual meaning in business and software architecture.

For others, a behavior is a state change trajectory - a “line of behavior” - showing how the value of a state variable changes over time. That is the usual meaning in system dynamics.

Two kinds of feedback loop

An important idea in activity systems thinking is the notion of feedback loops between systems, and between systems and their environments.

- "Self-regulating mechanisms have existed since antiquity, and the idea of feedback had started to enter economic theory in Britain by the 18th century, but it did not have a name.... In 1868, James Clerk Maxwell wrote a famous paper, "On governors", that is widely considered a classic in feedback control theory. This was a landmark paper on control theory and the mathematics of feedback." Wikipedia

Feedback occurs when the outputs or effects of a system influence its future inputs or effects.

Reinforcing feedback amplifies effects and can drive the state of things to an extreme.

- Population <increases> Births <increase> Population

Balancing loops dampen effects, and can maintain the state of a thing in a stable state.

- Population <increases> Deaths <decrease> Population

Note that biological evolution depends not only new generations, on the birth of children that differ slightly from their parents, but also, sadly, on the death of those parents.

In the second half of the 20th century, the concept of feedback loops informed three schools of activity system thinking.

Three schools of activity system thinking

Cybernetics (after Weiner and Ashby) grew out of studying how organisms and machines maintain homeostatic state variables using information feedback loops. Think of a thermostat-controlled heating system, or pancreas-controlled blood sugar levels.

- Feedback loops can connect a control system to a target system. Control involves a) a *receptor* that senses changes in the state of its environment or a target system, b) a *control center* that direct responses and c) an *effector* that changes the state of the target system.
- Observers may observe the current state of a system, and draw a graph to show how the system's state changes over time.

System dynamics (after Forrester and Meadows). A system is a set of stocks related and changed by flows. The stocks can be interacting resources of any kind, including biological populations in an ecosystem. The flows may represent streams of events.

- Feedback loops connect stocks (subsystems that respond to changes in each other) in a wider system or ecosystem.
- Observers may draw a causal loop diagram of flows between stocks, and draw a graph of stock level changes over time.

Soft (business) systems (after Churchman and Checkland). A business system is a set of inter-dependent *activities*, which *transform* inputs into outputs that *customers* want.

- Feedback loops connect a business to the environment the business operates in. A business must be able to a) read messages informing it of changes in the state of entities in its environment, and remember that state b) determine the appropriate responses and c) send messages that direct external entities to

perform particular activities, driving them forwards to some desired end state, or goal.
- Observers may draw a business activity model to show the dependencies between the regular activities, and read the current state of a system in its data store(s).

What is common to all three schools above? Regular activities. Ashby said his system is characterized by regular, determinate or repeatable behaviors. Meadows said Forrester's system is characterized by its activities and outcomes, rather than its actors. And Checkland defined his system in the form of a business activity model.

Note that to model an organic, social, economic or ecological system using the ideas above is to represent a *regular system*, even if it displays complex, non-linear, self-organizing or chaotic behavior.

Note also that a causal loop diagram of feedback loops represents a *closed system*, even if it has scores or hundreds of variables and feedback loops.

On Ashby's activity systems thinking

Ashby's classical cybernetic ideas include those discussed below:

1. Many if not most systems of interest can be modelled using discrete dynamics
2. An activity system applies a set of rules to a set of state variables
3. Adaptation by system mutation differs from adaptation by system state change
4. The relationship between abstract and concrete systems is many-to-many
5. Cybernetics explains self-organization as reorganization by a higher process
6. The law of requisite variety
7. Coding is ubiquitous in thought and communication (see Ref. 4)

Article 2 applies the ideas above to EA. This article picks out two general ideas that apply more widely.

Two kinds of process (deterministic and stochastic)

Ashby discussed how a system may respond to input events or disturbances in two ways - deterministic or stochastic (here called probablistic).

The earlier section on causality added a third kind of process, called possibilistic. Even this kind of process is "regular" in the sense that an actor is constrained to choose between a defined range of possible actions

Two kinds of system (abstract and concrete) - important!

Both cybernetics and enterprise architecture are about systems that can be modelled, and models that can be realized as systems. As Groucho Marx might have said: "An enterprise that is simple enough to understand without a model of it is one that doesn't need an enterprise architect."

System theory distinguishes activity systems from the physical entities that realize them.

- "a system... is independent of the concrete substance of the elements (e.g. particles, cells, transistors, people, etc)." Principia Cybernetica Web

Ackoff wrote:

- "different observers of the same phenomena may conceptualize them into different systems".

Ashby wrote:

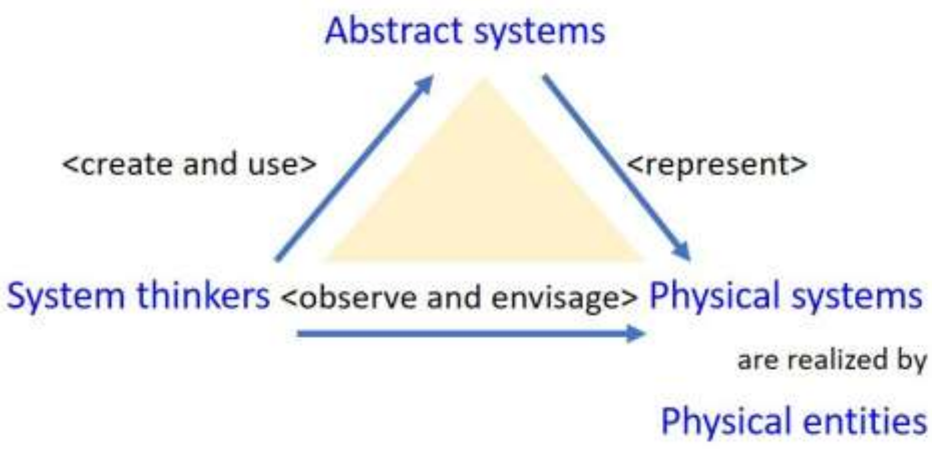
- 3/11 Our first impulse is to point at [some physical entity] and say "the system is that thing there" [however] every object contains an infinity of variables and possible systems. Any suggestion we study "all" the facts is unrealistic, and never [attempted]. [In practice we] pick out and study the facts relevant to some main interest already given." (Ashby 1956)
- 6/14 "the system" [is] ambiguous. [It] may refer to… the thing itself; or to the variables with which some given observer is concerned. Though the former sounds more imposing philosophically, the practical worker inevitably finds the second more important. … there can be no such thing as the behaviour of a very large system, apart from a given observer. For there can legitimately be as many [systems] as observers… which may be so different as to be incompatible. (Ashby 1956)

Since cybernetics is about systems that can be modelled, and models that can be realized, to apply it is to create a model of a system. The model defines the state space of the system, its state variables, and the activities that change their values. The model should be verifiable empirically and/or logically.

Ashby advised us not to point to an entity and call it a "system". He said one concrete physical entity may realize not just one, but countless different, and possibly conflicting, activity systems, each having its own roles and rules.

- A motor car is an entity that plays different roles in different systems, including the sales process of an auto dealer, the transport of bodies from A to B, and pollution of the atmosphere.
- A card school is an entity that realizes one system when its members play poker, and another system when its members share a pizza.

Actually, we need to distinguish three concepts - an abstract system description - its realization as a physical system - and the physical entity that does that. The triangle below distinguishes those three concepts, and relates them to systems thinkers who observe systems and describe them.



You might assume abstract systems (like the rules of poker) don't do anything - they are passive structures - merely descriptive representations of concrete systems. But abstract systems coded in the form of software can be executed. And Forrester's stock-flow models of system dynamics can be animated..

For more on Ashby's ideas, try Ref. 1.

On Ackoff's activity systems thinking

In "Towards a System of Systems Concepts" (1971) Ackoff set out more than thirty ideas about systems, starting with eleven terms and concepts that clearly derive from more general system theory and cybernetics.

1. **System**: a set of interrelated elements.
2. **Abstract system:** a system in which the elements are concepts.
3. **Concrete system:** a system that has two or more objects.
4. **System state:** the values of the system's properties (state variables) at a particular time.
5. **System environment**: those elements and their properties (outside the system) that can change the state of the system, or be changed by the system.
6. **System environment state**: the values of the environment's properties at a particular time.
7. **A closed system:** one that has no environment**.**
8. **System/environment event:** a change to the system's state variable values.
9. **Static (one state) system:** a system to which no events occur (its state does not change).
10. **Dynamic (multi state) system:** a system to which events occur (its state changes).
11. **Homeostatic system**: a static system whose elements and environment are dynamic.

Like Ashby, Ackoff discussed systems that are dynamic, open and abstracted from observations of real-world entities. He proposed we can abstract several systems from observing the behavior of one concrete entity. What Ackoff went on to say about human organizations as systems contradicted that last statement. We'll return to this later.

On Ackoff's view of parts and wholes

Like Bertalanffy, Ackoff characterized a system as a whole in which two or more parts interact, and parts as elements that affect the behavior of the whole.

Ackoff is often quoted as saying "Improving a part does not necessarily improve the whole". Contrary to what some interpret Ackoff as having said:

- Improving a part on its own is a reasonable way to improve the performance of the whole. Attending to the most costly part, or removing the largest bottleneck (one at a time) are recommended practices for improving a system. Such incremental development is a feature of biological evolution and agile system development.
- You can remove parts from a motor car without affecting its ability to meet its main aim (to carry people from A to B) since some parts interact to that end, but other parts (airbag, safety belt, carpet, arm rests, radio) are designed to meet other aims.
- The typical business "organization" is less-than-fully organized; it is a mess of aims and activities. "Managers do not solve problems, they manage messes". Ackoff.

For more on Ackoff's ideas, try Ref. 2.

SOCIAL ENTITY THINKING

In her Primer on Systems Thinking, Meadows defined a system in terms of not only actors and activities, but also purposes or aims.

- “A set of actors and resources that is coherently organized and interconnected so as to perform a characteristic set of activities, to achieve some aims".

Two branches of social system thinking

It is worth repeating what Seidl wrote.

- “The first decision [a theoretician has to make] is what to treat as the basic elements of the social system. The sociological tradition suggests two alternatives: either persons or actions." Seidl 2001

The two kinds of systems thinking sound similar, but are very different in practice.

- An **activity systems** is a network of regular activities - performed by actors (e.g. a solar system, or a poker game). It can be described using cybernetics, system dynamics, or soft systems methods. It can be represented in models, such as business activity models, process flow charts and data flow diagrams.
- A **social entity** is a network of actors - who perform activities (e.g. a tribe, or a card school). It is a group or network of actors who interact by communicating, by exchanging information. The actors may be more or less free to choose how they act, bearing in mind given aims, shared aims and individual aims.

Why say social entity rather than social system? Remember an activity system is a pattern, meaning there is some describable regularity or repetition, some orderliness, in its behavior. Paradoxically, some systems thinkers promote anarchical social structures and/or irregular one-off behaviors. They propose human actors respond to events and conditions as they choose, learn from experience and respond to novel situations in innovative ways. Which is fine. The trouble here is, it undermines the general concept of a "system".

Clearly, human innovation takes us beyond cybernetics. A human social entity is not limited to performing regular activities. And what we call an "organization" is not an organism or a machine; it is far more than any activity system we observe it as exhibiting. As Ackoff suggested, a business is more a *mess* of aims and activities than a single coherent activity system. Better, we distinguish social entities from activity systems they realize.

Two kinds of freedom (to select and to invent)

Freedom might be defined as the degree to which the actors in a system can make decisions and choose between paths. Ironically, every decision is a constraint in the sense that choosing one path denies another.

In an **activity system,** actors can select from a range of regular activities. The range is limited to what the system allows. Giving actors a wider choice of actions, a higher degree of freedom, increases the system's complexity.

In a **social entity,** actors may invent their own activities, even their own aims. They may do this without any overarching change control, and make ad hoc decisions that lead them down novel paths. If actors continually exercise their freedom (as autonomous agents) to innovate, then there is no regularity or repetition, and no recognizable activity system.

A history of human society, organization and civilization might be told in terms of social entity thinking scales including these:

- centralization <> decentralization
- standardization <> local variation
- planning <> agile experimentation
- discipline and repetition <> freedom and innovation
- hierarchical control and reporting <> peer-to-peer communication
- respect for a hierarchy <> anarchy.

Drawing the optimal balance between these extremes in the management of human institutions is a different matter from activity systems thinking. See article 2 for discussion of some of the scales above.

Ackoff's four-way classification of system types

Again, Russell Ackoff was a brilliant observer of humans, their institutions and their failings. There is much to enjoy in his view of motivating people to learn, the self-serving nature of the leaders of human organizations and other sociological phenomena. And there are things to dispute in his use of the term "system".

Ackoff's interest was in systems that are open and dynamic. They interact with their environment by consuming inputs, and producing outputs that change the state of that environment.

In an effort to build a unifying system theory that bridges the schism between machines and social entities, Ackoff built elaborate hierarchies of aims, activities and four system types. The table below is my attempt to stitch his system ideas together in a coherent whole.

Ackoff's classes	Actors (parts)	Activities (responses)	Aims (purposes)
State maintaining system	play roles in an activity system	no optional activities	fixed aims
Goal-seeking system		some optional activities	fixed aims
Purposive system	are members of a social entity	define their own activities	fixed aims
Purposeful sytem		define their own activities	define their own aims

This article draws a dividing line across this table.

Akoff's first two kinds of system appear to be *activity systems,* with a fixed range of possible activities. He surely realized they could be deterministic; I don't know if he recognized they could instead be probablistic or possibilistic.

Ackoff's primary interest was in *social entities* of the third and fourth kinds, in which actors can define their own activities, or even aims. He characterized them as being "purposive" or "purposeful".

Purposive or purposeful?

Ackoff's second two kinds of system are social entities in which actors have some freedom to change their activities or aims. The two may be differentiated thus.

- The purposes of a **purposive** system lie in the desire of external actors for the system to produce state changes in the state of its environment. The internal actors may be seen as slaves to that end.
- The purposes of a **purposeful** system are found in the desire of internal actors to produce internal and/or external state changes, which they define and can change.

In a "purposeful" social entity, actors have the freedom to change not only their activities but also their aims, in ad hoc ways. OK, but if there is no regularity or repetition, then what is systematic or systemic about it?

Ackoff's purposeful system "can change its goals in constant environmental conditions; it selects goals as well as the means by which to pursue them. It displays will." However, it does have one stable feature. - an "ideal" - which Ackoff said is unobtainable. Who defines it? Who knows what it is? Why can it not be changed?

For more on Ackoff's ideas, try Ref. 2.

Two kinds of purpose (intent and outcome)

Purposes can be intentions - aims we have - reasons to do things. Or else, purposes can be uses we find for things, and outcomes of systems we observe.

Purpose as intent

Many animals retain memories, so they can compare new sensations with remembered sensations. Some animals (not only humans) display consciousness of their environment. Consciousness give them the ability think about the past and envisage the future - to set aims and act to achieve them.

The concept of purpose implies envisaging a future, having aims, then acting with intent to reach them. To the extent that a system is shaped by the aims of external actors (sponsors, stakeholders, managers, designers and others) it may be called purposive. To the extent that the system is shaped by the aims of actors who play roles in the system, it may also be called purposeful. It can be both.

Purpose as outcome (POSIWID)

Some system theorists regard the emergent outcomes/effects of a system as its aims. Stafford Beer and other system theorists have said:

- "the purpose of a system is what it does" (POSIWID).

And Meadows' primer in systems thinking says:

- “A system’s function or purpose is not necessarily... expressed explicitly, except through the operation of the system. The best way to deduce the system’s purpose is to watch... how the system behaves. Purposes are deduced from behavior, not from rhetoric or stated goals.”

Teleology is the explanation of phenomena in terms of the purposes they serve, rather than of the causes by which they arise. But surely few would argue the solar system is explained by any purpose we may find for it? In Thailand, generations of macaque monkeys have used stones to open oysters and nuts. Surely few would argue the existence of the stones is explained by the uses monkeys make of them?

Biologists may speak of the purposes of the heart, or the liver, or a kneecap. However

- "The teleological metaphor was just a metaphor: underneath it lay quite simple mechanical explanations." "Today’s scientists are pretty certain that the problem of teleology at the individual organism level has been licked. Darwin really was right." https://aeon.co/essays/what-s-a-stegosaur-for-why-life-is-design-like

On the main ambiguity in systems thinking

In Meadows' Primer on Systems Thinking, the authors slip from discussing activity systems (networks of activities) in the first half to discussing social entities (networks of actors) in the second. They move from defining the dynamics of a system in a mathematical model of actors and interactions (from POSIWID) to saying

- "one of the most powerful ways to influence the behavior of a system is through its purpose or goal" - and to "a change in purpose changes a system, even if every element and interconnection remains the same".

This implies the behavior of a system (of the people who play roles in it) is affected by changing its explicitly expressed purpose(s), even though every role and interaction remains the same. Surely, you can't have it both ways: either the purpose is whatever a system does, or the purpose is what you intentionally direct or shape a system to do?

Obviously, everything we say, do or create can have effects that are mix of intended and unintended consequences, To speak of unintended consequences as being designed or purposeful seems perverse, however clever-sounding the resulting POSIWID aphorism.

Two kinds of organization (order and social structure)

Generally speaking, the term organization can refer to any order found in a structure, behavior or pattern of any kind. In much social systems thinking, the term organization refers specifically to a social entity in which actors are related in some kind of management structure, and perform activities, be they orderly or disorderly.

Questions to ask sociologically-included thinkers include:

- Do the words *society, organization* and *system* represent one, two or three concepts?
- How do they relate? Can one change without changing another?
- Can the actors in one organization act in different (perhaps conflicting) systems? Can they perform activities within the organization, yet outside any system? Can they perform activities outside the organization and any system it employs?

In terms of this article, the actors in a social entity may cooperate in activities to realize activity systems. And one activity system can be realized by several social entities.

Some thinkers slip, apparently unnoticed by their followers, from discussing activity systems to discussing social entities - using the same terms with somewhat different meanings.

Although Ackoff started with 11 ideas about systems (above) that are familiar to a cybernetician, his primary concern was human organizations. Curiously, his logic led him to say that every organization is a system, but not every system is an organization.

- “A group of unwilling slaves... do not constitute an organization, even though they may form a system”. Ackoff

Although Ackoff's writings on "social systems" are widely respected, they also exemplify the schism between social entity thinking and activity systems thinking. When he strove to apply cybernetic terms and concepts to human society, he contradicted himself on one critical point. To begin with he said:

- “Different observers of the same phenomena may conceptualize them into different systems”. Ackoff

Later, he expressed the opposing view that - regardless of different observers - every human organization is a system.

It is clearer to say that Ackoff's organization or purposeful system is one *purposeful social entity*, whose actors may play roles in *activity systems*, and may change those systems from time to time.

Social entity structures

How things connect in structures is the domain of graph theory, a field of mathematics that is well introduced by Robin Wilson. How far graph theory is relevant here is debatable. But for sure, a system may connect actors and/or activities in networks, hierarchies, chains and other topological patterns.

Sociologists have long studied structures that connect people in societies and business organizations. Note that where to draw the boundary of a social group depends on the interest, problem or requirement to hand. Social groups overlap, they merge, they divide; and some fight against each other.

See article 2 for discussion of hierarchical trees, the "servant leader", "autonomy" and "fractal".

Social systems as homeostatic machines

Towards the end of the 19 century, the notion of homeostasis appeared in biology. Claude Bernard discussed the need for an organism to maintain its state in equilibrium.

Early sociologists (who included Comte, Spencer and Durkheim) compared human societies to organisms. Spencer declared three principles for a social system:

- evolution (creates and changes a system)
- equilibrium (maintains a system in a stable state)
- dissolution (destroys a system).

Notice the principle of equilibrium. A common idea in sociology is that a society (or its members) resists changes. By contrast however, much modern social systems thinking discussion is less about stability, and more about system change, mutation or innovation.

CHANGE AND ADAPTATION

Remember, a system is a pattern, meaning there is some describable regularity or repetition, some orderliness, in its structure and/or behavior. Regular events can change the state of a system. Less regular events can change the system itself.

This section addresses points relevant to those who observe or design complex adaptive social entities. See the footnotes for further discussion.

Two kinds of change or adaptation (state change and mutation)

The word change appears more than 60 times in this article. Sooner or later, the environment of an activity system or social entity may change in a way that threatens its survival and prompt it to change or adapt in one of two ways. Adaptation can mean either.

- *changing state* yet remaining the same thing.
- *mutating* and becoming a different thing.

System state change

A system can adapt to changes or disturbances in its environment by returning itself to a desired state - as in a homeostatic organism or machine. Or else, a system's state can advance in response to inputs or actions - as when the score of tennis match advances - or an information system updates its internal memory to reflect changes it has detected in its environment. In both cases, the system's state changes, but its roles and rules remain unchanged..

System mutation

A system may be adapted to changes in its environment by mutation. This may happen by chance (as in biological evolution) or by design (as in business and software architecture).

Remember Google is said to have 2 billion lines of code. The remarkable thing is not the difficulty we have designing complex software systems; it is that we succeed at all. We do it by incrementally complexifying what starts - in version 1 - as a relatively simple system. We replacing each generation of the software system by the next. Biological species also adapt to environmental changes in this way - by inter-generational mutation.

When one generation of a system is replaced by the next, there is usually some kind of handover. And given limited resources, each generation must die to make make space for the next.

Some "systems thinkers" promote *continual innovation* in the structure or behavior of a person, society or a business. OK, but again, if actors continually exercise their freedom (as autonomous agents) to innovate, then there is no regularity or repetition, and no recognizable activity system. If no pattern lasts long enough to be described or followed, then there is no room for systems analysis or design.

Again, where actors invent actions, a social entity is not well called a system. So, might a CAS with human actors better be called a complex adaptive social entity (CASE)?

Two kinds of mutation (designed and accidental)

Here, the term design implies intent, which in turn implies there is a designer who makes a conscious effort to invent or change something. But mutations can be accidental.

- "Genetic mutations arise by chance. They may or may not equip the organism with better means for surviving in its environment. But if a gene variant improves adaptation to the environment (for example, by allowing an organism to make better use of an available nutrient, or to escape predators more effectively—such as through stronger legs or disguising coloration), the organisms carrying that gene are more likely to survive and reproduce than those without it. Over time, their descendants will tend to increase, changing the average characteristics of the population. Although the genetic variation on which natural selection works is based on random or chance elements, natural selection itself produces "adaptive" change—the very opposite of chance." https://www.ncbi.nlm.nih.gov/books/NBK230201/

A system mutation might incorporate a mix of designed and accidental changes.

Two kinds of "anti-fragility"

The terms robustness and resilience (or some say, antifragility) are used variously with reference to how a system is designed or evolves to survive. The terms are perhaps most simply distinguished as follows. To survive in the face of a changing environment or disruptive input.

- **A robust** system handles disruptive or unwelcome events and conditions (think. homeostasis, or immunity to infection).
- A **resilient** system mutates to handle new events and conditions (think (evolution).

How to design for anti-fragility? Read article 2.

Two kinds of agility

The two kinds are:

- **Agile system mutation:** Agile system development implies a designed system mutates in small ways, and frequently, from one generation to the next.
- **Agile activity system:** An agile activity system is one that can handle changes in its environment, without having to mutate when the environment changes.

How to make an agile business system? Read article 2.

Three kinds of self-organization

- "the term "self-organization" perpetuates a fundamentally confused way of thinking about how a system may evolve". Ashby

Ashby's analysis goes some way to reconcile second order cybernetics with classical cybernetics. It does that by placing one actor in two different roles - activity performer in a system and activity observer in a higher process, or meta system.

Discussions of self-organization can refer to at least three kinds of change; the last is the most interesting here.

- *Goal-seeking state change*. An entity is drawn to one or more "attractor" states and resists being moved from such a state - as in homeostatic biological and electro-mechanical control systems.
- *Self-assembly or growth*. This is another kind of state change. An entity grows incrementally by adding more elements or actors to its body. E.g. the growth of a crystal in a liquid, or a plague of locusts.
- *Self-improvement*. This is a kind of state mutation. Self-improvement implies changing from "bad to good" in some way. Ashby's way of thinking about this is discussed below.

Ashby's alternative to second order cybernetics

Seeking to apply cybernetics to human society, Heinz von Foerster introduced what he called "second order cybernetics". He proposed the actors in a system can not only perform activities, but can also observe and "improve" those activities as they choose.

The vision is not of an activity system but rather an agile social entity in which actors can determine and change the activities they perform, and perhaps also the aims they strive to meet.

Both Ashby and Maturana rejected this kind of "self-organization" as undermining the very concept of an activity system, in which actors are defined by their roles in interactions.

Ashby applied classical cybernetics to self-organization and evolution by coupling a "lower" system to a "higher" system. The higher level system observes the state of things, and when circumstances demand it, changes the roles and rules of the lower system. By doing this, the higher system creates a new lower system or system generation.

Can we apply Ashby's idea to social entities? Yes. In social activity system thinking, one actor may play two different roles:

- one role in the operation of an activity system (S)
- one role in a higher process or meta system (M) that observes and changes system (S).

This approach - here called meta system thinking - goes at least some way to remove the need for a "second order cybernetics". It does however presume that a system evolves by inter-generational steps. In the case of human activity systems, this implies some kind of change control.

For more on Ashby's discussion of self-organization in cybernetics, read Ashby's six core ideas. It turns out that Ashby's idea can be applied in a wide variety of domains. This article calls it meta system thinking.

Meta system thinking

Meta systems thinking separates the roles in a system S from the roles in a higher process or meta system M (which can observe and change the behavior of S). And allows that one actor can play a role in both systems.

- In Ashby's example, the meta system changes the rules of a homeostat when its state variables move beyond an acceptable range.
- In sociology, the meta system is some kind of council or committee, which observes the activities of community members, and sets rules for the community to follow.
- In biology, the meta system is evolution. The inter-generational changes are tiny, and very few prove beneficial. Nature does not observe the success or failure of organisms; it simply eliminates ones that don't work or consume too many resources.

EA can be seen as meta systems thinking. For meta systems thinking in business and software architecture, read article 2.

Meta meta system thinking

A higher process or meta system (M) is one level up from the base level system (S) that it may observe and change. E.g.

- the process of biological reproduction is one level up from the lives of individual organisms
- the Lawn Tennis Association is one level up from the progress of tennis matches around the world.

We could pitch every meta system at level 2. Or else, speculate about a system S with several levels of meta system above it (M, MM, MMM…).

In stretching Ashby’s ideas about mechanical, biological and psychological machines to the level of sociology, we reach the level where people act with intent; they envision future changes, make decisions and act accordingly. But when we reach the level of people with consciousness of the future, with the ability to invent new system roles and rules, we’re at a level where Ashby's kind of system is at best a partial explanation of reality.

On the inexorability of change in human society

Human society is not a designed system; it evolves with or without government.

Leaders change their minds. The paradox of policies announced and imposed by governments is that - as people adapt their behavior - they lead to unintended consequences that create the need for new policies, sometime reversing the original ones.

Electors change their leaders. The strength of a democracy lies less in the ability to elect a government who promises to do certain things, and more in the ability to unseat that government in the light of what it does. The incoming government is chosen precisely because it promises to do something different.

It might be argued that economic and social progress is a process of trial and error that depends on leaders changing their minds and electors changing their leaders, supported by the trial and error process of science that tries to crystallize stable knowledge for future use.

DATA AND INFORMATION

In general, systems, and the actors within them, may be connected by flows of energy, matter, forces or information. The focus of cybernetics and enterprise architecture is on information flows. The actors in a system can remember information in memories and communicate information in messages. Memories and messages contain data structures.

Actors create and find information in messages and memories by encoding meaning in symbols, and decoding meanings from symbols, using a language. Successful communication in a system requires its actors to share a language - to share the meanings of symbols created and found in messages and memories.

In practice, the words data and information are used interchangeably, because it is assumed that the senders and receivers of a data structure will create and find the same information in it. This means that the data and the information are in 1-to-1 correspondence.

In theory, data and information are separable concepts. Some position them in a hierarchy of Wisdom, Knowledge, Information and Data (WKID). Here is a way to make sense of that hierarchy.

- **Data** = a structure of matter/energy in which information has been created (encoded) or found (decoded).
- **Information** = meaning created or found in data by an actor.
- **Knowledge** = information that is accurate enough to be useful.
- **Wisdom** = the ability to apply knowledge in new situations.

Any physical structure of matter or energy can be used as a data structure or signal. It becomes one in the moments when it is encoded to convey information/meaning, or decoded as conveying information/meaning.

The meaning is not in the message

Counter-intuitively: *there is no meaning in a message on its own*. Meaning only exists to a writer in the process of writing a message - and to a reader in the process of reading a message. Information is a logical phenomenon that is created or found by an actor when performing a data coding/decoding process - it only exists in that encoding or decoding process.

One message can have different meanings to its writer and its readers . For the meanings to be the same, writers and readers must share the same code, and perform compatible encoding and decoding processes.

In short, the meaning is not in the message, it is in a process that encodes or decodes the message. If you need to be convinced or this, and for more on the communication of knowledge between social actors, read chapter 1 of this article on the meaning of meaning.

Language and meta data

Defining the data structure of a message is not enough. Biological evolution equipped people to codify meaningful information into words that others can decode back (near enough) into same information. To do this, to succeed in communicating, the communicating actors must share the same code or language. In designing information systems, the meaning of data is defined meta data.

Note that Shannon's "information theory" says nothing about meaning (information); it is only about signals (data structures). Until recently, the technology people used to form data structures was sound waves or written symbols, which can be damaged by noise or material decay. Thanks to Shannon, today's information technology preserves the integrity of a data structure from end to end of a message transfer. But that has nothing to do the processes actors use to encode meaningful information in a message or decode it.

CONCLUSIONS AND REMARKS

Every human society and business might be described as mix - as people in a social entity who cooperate to realize any number of activity systems. While you can and should use a mix of approaches, you should recognize the two schools are very different. They lead to different ideas about what it means for a system to be defined, to exist, and to change or evolve. Systems thinkers should be clear which they are thinking and talking about.

Enterprise architecture is primarily about the design and planning of activity systems (networks of activities) and secondarily about social entities (networks of actors). Motivating and directing the latter is more the domain of business and project managers.

On first and second order cybernetics

Some present the history of systems thinking as a sequential evolution (for example, see my comments on Midgely's version of the story).

However, second order cybernetics is not a later generation of classical cybernetics. It is a different thing. Its advocates tend to confuse social entities (in which actors interact as they choose) with activity systems (in which actors play agreed roles) realized by social entities. Ashby's view of self-organization gives us an alternative view of how actors can reorganize systems they play roles in

On social entity thinking

Clear systems thinking requires people to recognize social entity thinking is not a later generation of activity system thinking. Social entity thinking is a different thing, and it suffers from three general issues:

- Pseudo-science. Systems thinkers often take words from one science and apply them in another, usually sociology, in different or questionable ways. This is not generalization, it is diversification, and it leads to cross-domain misunderstandings.
- Post-modern relativism. The (hermeneutic?) idea that there is no objective meaning, that the reader determines the meaning of what another has written. It doesn't matter what a writer meant as long as readers interpret it in a way they like.
- The ambiguity of "not-deterministic". When people say a CAS is not deterministic, what do they mean. Which of three kinds of not-deterministic (probabilistic, possibilistic and innovative) are they thinking of?

Activity systems thinking addresses deterministic, probablisitc and possibilistic processes. So, it is sufficient and efficacious for modelling orderly human activity systems. It is not enough for analyzing a messy and purposeful social entity or situation. For that you may consider meta system thinking (above) and general morphological analysis (above), and countless classification schemes and mental models for understanding, shaping and steering social entities associated with the name of their inventor.

Bear in mind it is difficult to define the concept of a society or social entity in way that is both widely agreed and useful. We can say it is a group of communicating animals who influence each other's behaviors, but that begs questions about how and when animals join or leave the group.

On terminology

You can't have a coherent conversation, let alone a scientific discipline, without (near enough) agreeing the information/meaning encoded in (most of) the words you use. If you are intentionally vague about what words mean, then you are more poet than scientist.

Generalizing the word "system" to the point of vacuity reduces the value of the word "system" in system science, which does give us good and useful ways to model and discuss human activity systems, and even to discuss the "self-organization" in human organizations.

Some social entity thinkers

- deprecate a "traditional reductionist approach" that nobody has ever used to design a system, since holistic thinking is the very essence of system engineering,
- dismiss system engineering as linear thinking, though simple machines can behave in a non-linear, unpredictable and chaotic ways.
- propose we design systems to be "adaptive" or "antifragile", without considering the extra cost, complexity and resource use this likely requires.
- take the (subjectivist, perspectivist or relativist) view that any interpretation of a systems thinker's model or theory is equally valid.

If we want "systems thinking" to be meaningful and useful then we should use a coherent and consistent terminology, promote what makes sense, deprecate what doesn't.

Ackoff was a brilliant observer of human society, its institutions and their failings. He might well be put on a social entity thinking pedestal and seen as a CHAT authority (Ref. 5). However, some of what he said about activity systems was misleading, and encouraged the very confusion of human organizations with activity systems that he tried to distinguish.

Conclusion: where actors invent actions, a social entity is not well called a system. A CAS with human actors may better be called a complex adaptive social entity (CASE).

- CASE: a social entity that realizes activity systems (modellable as in cybernetics or EA) and revises/adapts those systems when needs arise.

FURTHER READING

An influential or oft-quoted teacher or expert is often called a guru. Systems thinking gurus include Ackoff, Ashby, Beer, Capra, Checkland, Churchman, Forrester, Jackson, Meadows, Midgely, Ostrom, Senge, Snowden and Von Foerster. This article has only mentioned a few.

First two primary sources and my analysis of them.

- Ref. 1: Ashby's "Introduction to Cybernetics" 1956. For my analysis, read Ashby's six core ideas.
- Ref. 2: Ackoff's "Towards a system of system concepts" 1971. For my analysis, read Ackoff's ideas. In the first third of this article, Ackoff says a few things disputed above.

Next, some notes supporting this article.

- Ref. 3: On Bertalanffy, here are some interesting notes I don't entirely agree with: On the history of Ludwig von Bertalanffy's "General Systemology", and on its relationship to cybernetics.
- Ref. 4: This companion article further explores the distinction between social entity thinking and activity systems thinking. It also distinguishes data,

information, knowledge, wisdom, and relates enterprise architecture to systems thinking and design thinking methods.

- Ref. 5: On CHAT. From Wikipedia: "Cultural-historical activity theory (CHAT) is a framework which helps to understand and analyse the relationship between the human mind and activity... Core ideas are: 1) humans act collectively, learn by doing, and communicate in and via their actions; 2) humans make, employ, and adapt tools of all kinds to learn and communicate; and 3) community is central to the process of making and interpreting meaning – and thus to all forms of learning, communicating, and acting.|"

Finally, two longer articles related to this article.

- Systems thinkers and their ideas
- The meaning of meaning, typification and truth

FOOTNOTES on complexity, catastrophe, chaos, etc.

Dave Snowden has distinguished complex adaptive systems (footnote 2) from other systems by defining them as dispositional (footnote 1) rather than linear casual (footnote 3). This may be to use those terms in very particular ways, but it entangles ideas that merit attention as distinct concepts. Let us start with dispositional.

Footnote 1: Dispositional

Disposition: "A) prevailing tendency, mood, or inclination. B) temperamental make up. C) the tendency to act in a certain manner under given circumstances." Merriam Webster

Note that meanings A and B apply to people, but C is the more general meaning of disposition used in philosophical discussion of causality, where things have **dispositions** to act or change in some way when triggered by a cause, by a describable event or condition. E.g.

- A wine glass is disposed to ring or shatter when struck.
- A cooling system is disposed to start up when the air gets hot.
- A person is disposed to shiver when cold.
- A species is disposed to acquire new characteristic(s) when a child is born.
- A democracy is disposed to replace one government by another.

Consider the disposition of a wine glass to ring or to shatter when struck. The cause-to-effect process is non-linear in the simplest sense - there are two possible outcomes. The glass "chooses" which to do depending on the force and location of the strike, and its own current state. The outcome may be predictable in theory, but unless the strike is hard, it may be unpredictable in practice.

Human dispositions are malleable, and the human actors in an organization may change how that entity is disposed to respond to events and conditions. Whether an ever-changing social entity is well called a system is questionable, as has been discussed.

Footnote 2: Complex Adaptive Systems (CAS)

What is a CAS?

The terms Complex, Adaptive and System (CAS) can each be used for an idea that is interesting and valuable on its own. However, you only have to skim the systems thinking literature to find different interpretations of the terms, separately and together.

It seems the current consensus is that CAS does not have a strict definition. It is a collection of attributes, not all of which are necessary to be called a CAS. And CAS may have its own meaning in one school of thought, regardless of specific meanings attached to C, A and S.

- **Complexity** usually implies there are many actors or agents. But any human social entity, from a small family business to an army, may reasonably be called complex,
- **Adaptation** implies actors adapt to events and conditions (internal and external). They don't settle into a stable state or equilibrium. Note that any human social entity may reasonably be called adaptive. And note that while continual state change is one thing, continual mutation of the system itself is another, since it undermines the general idea that a system is a pattern, with some regularity or repetition that can be modelled.

Source 1: the Merriam Webster dictionary defines relevant terms as below.

- **Complex:** "a whole made up of complicated or interrelated parts." Note that since different observers may divide the same thing into different parts, the complexity of a thing necessarily relates which description you have in mind.
- **Adaptive:** Marked by "adjustment to environmental conditions: such as A) adjustment of a sense organ to the intensity or quality of stimulation, and B) modification of an organism or its parts [to better fit] the conditions of its environment." Note the dictionary examples illustrate two different kinds of change. Whereas A is a state change in an organism's life time, B is an inter-generational mutation.
- **System:** "a regularly interacting or interdependent group of items forming a unified whole." Note that in activity system thinking, regular means rule bound, but in social entity thinking, it might instead mean frequent., rather than rule-bound.

Source 2: Axelrod and Cohen define a CAS in terms of characteristics found in a simple systems and human organizations.
http://innovationlabs.com/harnessing_complexity.pdf

- "A "system" includes one or more populations of agents and all of the strategies that those agents employ."
- "A "complex" system is one in which the actions of agents are tied very closely to the actions of other agents in the system."

- "When the agents in a system are actively trying to improve themselves ("adapt"), then the system is a Complex Adaptive System."

Yet the simplest of deterministic systems may have many component or actors/agents, which interact closely with each other, and produce emergent properties. And the notion that actors may adapt by learning and seeking to improve themselves shows the authors are thinking of a human social entities in particular, rather than systems in general.

Again: where actors invent actions, a social entity is not well called a system. A CAS with human actors may better be called a complex adaptive social entity (CASE).

- CASE: a social entity that realizes activity systems (modellable as in cybernetics or EA) and revises/adapts those systems when needs arise.

What is complexity science?

Overviews of "complexity science" tend to present a jumble of ideas from mathematics to sociology, which makes it difficult to define the whole field in a coherent way. And there are, as you may expect, ambiguities in the terminology used.

Complex things and complicated models

Some in the field of complexity science presume a thing has an intrinsic amount of complexity - independent of any observer's perspective, description or model of that thing. But as Ashby pointed out, the complexity of every substantial physical entity is well-nigh infinite, and certainly far beyond any model we can make of it. The only complexity we can meaningfully discuss is that of a model or description of a thing. And even that is measurable in a variety of ways. For example:

- The most complex kind of model we produce is the code of a software system. As a measure of complexity, you might count lines of code. There are said to be 50 million lines in Windows, and 2 billion lines in Google. Else, you might measure the logical complexity of a system's component structure, or of it procedures, in various ways.
- Still, there is even more complexity to be found in the physical entity that is a software system in operation. Consider not only the number and variety of the states the system occupies over time, but the structure and behaviors of the electronics and computing hardware, all the way down to subatomic particles and their movements.

One way to disambiguate the terminology is to say "complex" when speaking of a real-world thing or situation and "complicated" when speaking of a description or model of it.

- "complex is a term we use for something we cannot yet model. If there is nothing metaphysical about a complex system... then perhaps a complex system is ultimately nothing more than extremely complicated." Cilliers quoted in https://digifesto.com/2020/09/01/on-cilliers-on-complex-systems/

Cilliers didn't quite say so, but he implied that systems thinkers say "complex" when thinking of a real-world thing, and "complicated" when thinking of a thing in terms of a description or model of that thing

The general issue in systems thinking is not so much the complex/complicated distinction as the entity/system distinction. As Ashby pointed out, an entity is not a system, it is as many systems as observers choose to abstract from it. And its complexity can only be assessed with respect to one such model.

How to assess complexity?

Is a thing complex because it is messy, disorganized or ever-changing? Surely, if there is no regularity or repetition, there is no system? To call something complex is to imply it is organized or orderly in some way?

Is complexity found in the organization of a system's structure and/or its behavior? Here are some very simple structures with surprisingly complex/complicated behaviors.

- A structure with two actors https://www.youtube.com/watch?v=U39RMUzCjiU
- Just one actor https://www.youtube.com/watch?v=wcKyq-e-Soo

Is complexity found by counting a system's elements? Do we count the number of entity and event *types* in a system's description? Or the number of entity and event *instances* in the run-time operation of a system?

You cannot measure the complexity of a thing directly. You can only measure it with respect to a particular description its properties. The amount of complexity you find depends on the level of abstraction from physical reality at which you describe the thing, the dimensions you choose to describe, and how you account for variety, volume and entropy.

- *What is the level of abstraction?* To compare the complexity of different things - the atomic level of description must be agreed. How far a description is abstracted (from the sub-atomic particles of a system in operation) is discussed in Brooks' no silver bullet article.
- *Which dimensions are of interest?* There is complexity in the memories actors maintain, the messages actors exchange, the network in which actors connect, the activities actors perform, the resources actors need, and the trajectories of state variable value changes over time.
- *Do we count variety or volume?* Do we count the *types* in a system's description. Or do we count the *instances* in a system's operation?
- *Entropy?* See footnote 5.

In practice, scores of complexity measures have been proposed, and measuring every conceivable dimension of a system is too difficult. We do make subjective comparisons. However, to say the complexity of a thing is *only* in the eye of the observer seems unhelpful. We should use a measure of complexity that is found in a description agreed by communicating observers, and agreed by those observers as useful for their purposes.

What is complexity science?

One source defines the following as features of a complex system. It is **open, non-linear, chaotic, multi-dimensional** and **adaptive** or s**elf-organizing**. Yet

- A simple system can be open. And a closed system can be complex. Consider an ecology as in modeled in causal loop diagram.
- A simple system can produce a non-linear line of behavior. Consider a double pendulum.
- A simple system can have a non-linear disposition. Consider that a wine glass is disposed to one or other of two possible effects when struck.
- A simple system can be chaotic. A predator-prey system, given slightly different initial populations, can produce very different outcomes and population crashes.
- A simple system can have the same dimensions as a complex one.
- A simple system can adapt. Consider a cooling system adapting to temperature change.

Another source on "Understanding Complexity" https://amzn.to/2ETI886, says complexity concepts include the following.

- Tipping points. The sociological term used to describe moments when unique or rare phenomena become more commonplace.
- The wisdom of crowds. The argument that certain types of groups harness information and make decisions in more effective ways than individuals.
- Six degrees of separation. The idea that it takes no more than six steps to find some form of connection between two random individuals.
- Emergence. The idea that new properties, processes, and structures can emerge unexpectedly from systems in operation.

These look like an arbitrary jumble of ideas. And by the way, in the "risky shift phenomena" identified by by James Stoner in 1961, people change their decisions or opinions to become more extreme and risky when acting as part of a group, compared with acting individually; which is one form of group polarization.

Footnote 3: Catastrophe and chaos

Catastrophe. A discontinuity in a state change trajectory (which appears as a sudden large jump or fold in a line-of-behavior graph) is called a "catastrophe" in system theory. At a longer scale it might look more continuous.

Chaos? Ambiguous! In mathematics, a chaotic system is one whose state and line of behavior is highly sensitive to initial conditions. A system whose state is stuck in a "strange attractor" may be called chaotic; yet undergoes no catastrophe.

In activity systems thinking, chaos may mean a system changes in apparently random or irregular ways, even though the activities are regulated by deterministic rules.

In social entity thinking, chaos might mean actors' activities are not organized, not rule-bound, and no pattern can be detected how actors interact (there is no activity system).

The edge of chaos? This phrase has no precise and general definition across domains where it is used. It gives the impression of something profound when little has been said. Informally, it means a phase transition in a system from a predictable regime to chaotic regime. Still, both regimes are deterministic.

Predictable, controllable and stable - different ideas. A system may be predicable without being controllable. A system may be both, yet not stable in the accepted technical sense.

Footnote 4: Linear v non-linear

Linear: in a straight line. Which sounds simple, but the term is applied by different people in different situations with different meanings.

Linear cause: A cause that leads to one effect. It implies a straight line from cause A to effect B.

Linear line of behavior: A state change trajectory that runs straight line when drawn on a graph of state change over time.

Linear thinking: a term used as an insult.

Non-linear is applied by different people in different situations with many different meanings.

Non-linear in natural language

The term means not in a straight line. So, in activity systems thinking, it could mean a line of behavior that is curved or jagged (perhaps an exponential increase or decrease, or a sine wave, or more complicated). E.g. consider unit price movements in a stock market, or the number of people infected by a virus.

Non-linear systems in mathematics (after Will Harwood)

A relationship between x and y is linear if y can be expressed as ax+b. A function f is said to be linear if f(ax) = af(x) and f(x+y) = f(x) + f(y). A system is linear if it is described by a deterministic linear differential equation.

A system is non-linear if it is described by a deterministic non-linear differential equation. And a system is non-linear if it is described by a stochastic differential equation.

Non-linear systems in system dynamics (after Will Harwood)

A causal loop diagram shows a set of flows between stocks, where the flows increase or decrease those stocks. Some systems thinkers call the described system linear if it has no feedback loops; and call it non-linear if it shows at least two stocks connected by a feedback loop. (That is a different distinction from the one drawn by mathematicians above.)

A causal loop diagram is a sketch of a system's dynamics. The diagram is drawn with + and - signs on the flow arrows to show which flows (or activities) increase or decrease the stocks (or resources). For examples, see this introductory book https://bit.ly/3blcJaT.

A causal loop diagram can be a good way to tell a story, or express a hypothesis about the world. However, it does not show all the quantitative features of stocks and flows needed to complete a system dynamics model (or the differential equations that define the dynamics of the system). So, it is not enough to reveal all the behaviors the system could exhibit.

Proving such a diagram to be a usefully accurate model is very challenging. You may be confident, from your experience of the world, that the + and - signs on the flow arrows are correct, but the strength of those of effects may be unclear. You have no obvious way to judge whether critically important stocks or flows have been omitted from the model (e.g. the impact on the Covid virus population of vaccinations or social distancing policies). And short of adding the mathematics, supplying some initial values to the stocks and running some simulations, it can be hard to be sure what effects the passage of time will produce. Moreover, some would characterize a "complex system" as one that, given different initial values, can produce very different outcomes!

Non-linear information systems

Most business information systems are connected in a feedback loop with entities in their environment. E.g. Outputting an order triggers an invoice to be input, which triggers a payment to be output, which triggers a receipt to be input. Yet most systems thinkers would probably call the system linear.

Non-linear social entities

Social entity thinkers sometimes use the term non-linear to describe human, rather than demonstrably deterministic, behavior. Whether human thinking is deterministic or not at some level of biochemistry, we have no option but to treat people as having free will.

Footnote 5: On thermodynamics, entropy and energy

Social systems thinking is at some remove from cybernetics, which is at some remove from thermodynamics. In his Introduction to Cybernetics, Ashby wrote:

- 1/5 “In this discussion, questions of energy play almost no part—the energy is simply taken for granted.” "Even whether the system is closed to energy or open is often irrelevant”.
- 4/15. Materiality: “cybernetics is not bound to the properties found in terrestrial matter, nor does it draw its laws from them.” “What is important is the extent to which the observed behaviour is regular and reproducible.”

- 7/24. Decay of variety: “any system, left to itself, runs to some equilibrium”. “Sometimes the second law of thermodynamics is appealed to, but this is often irrelevant to the systems discussed here."
- 9/11. Entropy: “Shannon has devised a measure for … entropy—that has proved of fundamental importance …” “The word “entropy” will be used in this book solely as it is used by Shannon; any broader concept being referred to as “variety” or in some other way.” Thus, Ashby distinguished entropy of communication theory from entropy of thermodynamics.

A whole is in a disordered state if there is no correlation between its parts. That is to say, knowing the state of one part gives no information about other parts.

One source defines entropy as the number of ways such *uncorrelated* parts of a whole can be configured. The higher the number of parts, the higher entropy of the whole since there are more ways in which to arrange the parts.

However, if you define one configuration, then organize the parts to match it, you are imposing order on the whole (which requires energy). Designing a system for adaptability may involve complexification - increasing the number of ways parts can be configured - and increasing the variety of system states.