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The Human Activity System: Emergence from Purpose, Boundaries, Relationships, and Context

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Abstract

Systems engineering is a human activity system that depends on highly specialized technical knowledge to design, model and realize complex systems. However, as yet there is not enough specialized technical knowledge that can assist systems engineers to design and evolve the human activity systems as such. In this manuscript, we propose a human activity system model and a set of principles to guide the design and evolution of human activity systems that design, model, and realize complex engineered systems. The significance of this development for systems engineering is that attention is brought to the critical need to develop scientifically derived methods to design robust human activity systems

Keywords: human activity system; purposeful; systems principles; systems thinking; systems concepts

1. Introduction

Systems engineers increasingly recognize that future systems will be engineered by an evolving and dynamic workforce [1]. This is a crucial insight given that most systems engineers' training focuses on system design, representativeness of system models, and system realization processes. However, in practice, the system realization processes typically do not fully take into account the design of the human activity systems that will design, model, and

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realize complex systems. This is a consequence of the currently undeveloped state of the knowledge base necessary for establishing, in a disciplined and objective way, the systems design, modeling, and realization activities as human activity endeavors. Between 2015 and 2018 there have been two important developments that provide new avenues towards developing this knowledge base. First, the recognition that systems engineering practice can be improved with the use of principles [2]. As such, Rousseau et.al. [3] have acknowledged the need to develop scientific principles to guide all phases of systems engineering. Such principles can make systems engineering processes more robust in the face of the rising complexity of both demanded engineered systems and the required systems realization processes. Second, INCOSE's Systems Engineering Principles Action Team and the Systems Science Working Group have ongoing projects responding to the call.

Having established the imperative to have scientific principles to guide systems engineering, it is relevant to highlight the need to have a more specialized set of principles to guide how systems engineers will design and manage human activity systems. And because systems engineering is considered a human activity system [4], systems engineers form human activity systems when they come together to enable systems engineering practice. Thus, such human activity systems must interact, as systems, with other systems engineers, with machines, with software, with AI systems, with methods, processes, models, theories, etc. However, this presents a problem when the introduction of new technologies produce unprecedented scenarios, because in these cases there are no 'best practice' precursors. In such instances, questions about how to reach congruence between idealized human activity systems and their instances cannot be confidently addressed because of the current lack of relevant scientific models and methods. This problem is becoming increasingly common due to the accelerating rate of technological progress in the current era [5].

In this manuscript we present an introduction to the concepts and issues around the development and management of human activity systems. We will present design principles and foundational theories that explain why and how human activity systems emerge. We do so by applying Cabrera's [6, 7] DSRP, Rousseau's general systems principles [8], and Rousseau, Billingham and Calvo-Amodio's Systemic Semantics framework [9]. Finally, we will provide an example that illustrates how to apply the principles we propose.

1.1. Systems principles

David Rousseau [8] introduced three general scientific systems principles that present some of the most fundamental concepts about how and why systems emerge, transform, and evolve. The first general scientific principle captures the relationship between (on the one hand) a system's emergent processes, behaviors, structures, and/or meanings and (on the other) its parts' submergence of their capabilities, boundaries and significance, as the stability of the newly emerging system is achieved. This first principle: conservation of properties states that "emergent properties are exactly paid for by submerged ones" [8]. The second principle acknowledges that systems are part of higher domain systems that condition the potential of the system of interest. In other words, the system's parts possess a determined potential to create an emergent system, but the higher domain system will determine how much of that potential is realized. This second principle: Universal Interdependence is important because it enables us to realize that a system's potential is not only dependent on the contributions the parts make, but also on what is subtracted by the higher-order system. Bottomline, this means that, unlike as in classical reductionism there are two explanatory arrows, one (going up from the parts towards the boundary) for the bottom-up emergence and one (going from down from the environment towards the boundary) for out-side in submergence. Finally, the third principle establishes that the balancing between a system's inherent potential and its contextual suppression by the higher-order system is not always straightforward. It can be seen that, in addition to the explanatory arrows that explain emergence/submergence pointing up and down towards the boundary, these arrows can differ in size (power) due to complexity differentials between system and higher-order system. Complexity dominance, the third principle, encourages us to consider the significance of the difference between kinds of complexity and degrees of complexity systems have. Doing so enables us to use variety engineering to manage complexity accordingly.

Emergence in human activity systems is consistent with the three general scientific systems principles. Teams emerge from individuals coming together and suppressing certain behaviors that do not match the imperatives of the team environment; the same behaviors are again available as soon as individuals leave their team environment. The higher-order system also influences the potentials of teams; for instance, site regulations, organizational culture, etc.

Finally, some teams can exert considerable influence on their environments if their behavior is complex enough to overcome the constraining influences of the higher-order system.

1.2. Systemic semantics

Rousseau, Billingham, and Calvo-Amodio [9] presented a framework for creating ontologies (termbases) through the application of systems concepts, by linking kinds of systems concepts to general kinds of lines of inquiry. The work stems amongst many factors from the recognition of (on the one hand) principles governing the stability of enduring systems [3], through (on the other) universal categories of thought that characterize distinct kinds of knowledge [10]. Now, given that ontologies are systems, and that they capture the foundational information contained in kinds of knowledge [10], it is now possible to develop a systemic framework for organizing knowledge about human activity systems. This opens up a systematic way to leverage this knowledge in the light of existing knowledge of both general systems principles and systemic isomorphisms –similar patterns of structure or behavior that occur across systems scales and kinds. This conjunction can help to identify routes to achieving robust and optimal designs of human activity systems.

Table 1 contains a non-exhaustive set of categories and concepts pertaining to human activity systems. Table 1 serves as the foundation for the remainder of this manuscript where we provide definitions for the main components of the human activity system model, their associated principles and concepts.

Table 1. Top Categories and Concepts of the Human Activity System Ontology Development (adapted from [9, 10])

General Inquiry Component	Information Component Questions	Human Activity Systems Concepts
Ontology of human activity systems	What are human activity systems? How can we recognize a human activity system?	Boundaries, relationships, process, context, perspective (weltanschauung), concrete, conceptual, parts, structure, emergence, interdependence.
Metaphysics of human activity systems	What is the nature of a human activity system? What makes a system a human activity system?	Purposeful, flexible, adaptive, collaborative, learning, appreciative.
Cosmology of human activity systems	How do human activity systems arise and evolve? How are human activity systems organized? How do they change?	Physical systems, sapient systems, socio-technical systems, conceptual systems, systems of systems,, goal seeking, transitions (transformation), self-organization, evolution, homoerhesic, homeostatic.
Axiology of human activity systems	Why are human systems important to systems engineering practice? What makes a good human activity system?	Effective, efficient, efficacious, ecological, robust, resilient, agile, evolvable, coherent, productivity, external compatibility.
Praxeology of human activity systems	What is the purpose of a human activity system? How is its purpose achieved?	*Concrete purposes*: survival, competition, evolution, transformation, innovation, learning. *Conceptual purposes (meanings):* persuasion, motivation, anticipation.
Epistemology of human activity systems	How do we know a human activity system is successful? How can we obtain knowledge about human activity systems?	Models and principles; isomorphisms, system analysis, measure of success.

2. The human activity system model

In practice, people presently design human activity systems intuitively, so that for them the system is what they say it is. However, this is a cognitive trap because under that perspective it looks as if it might be easy to design a human activity system and it can be done subjectively. In reality, we need an objective model that can be shared so that skills can be developed to design human activity systems in a principled manner, and designs can confidently be adapted to meet unprecedented scenarios. In this light, we propose that it would be valuable to adopt, apply and further develop human activity systems models such as the one introduced in this paper.

2.1. Distinctions, System, Relationships, Perceptions

An inherent and essential component to the work presented in this manuscript is systems thinking. Systems thinking lacks a unified definition. The many definitions for systems thinking tend to be biased by the context, purpose, analyst perspective, scale, and kind of target system to which systems thinking is applied. Derek Cabrera [11] developed a definition and a framework that provides, in our view, the most robust depiction of what systems thinking is, because he used formal scientific methods in its development. Systems thinking is defined by Cabrera as:

> *"a conceptual framework, derived from patterns in systems science concepts, theories and methods, in which a concept about a phenomenon evolves by recursively applying rules to each construct and thus changes or eliminates existing constructs or creates new ones until an internally consistent conclusion is reached"[11] .*

Cabrera recognizes four skills necessary to be a systems thinker: 1) Distinction making between what is and is not part of a system, 2) Organizing systems into wholes or smaller parts, 3) Relationship identification between concepts and interactions between them and, 4) Perspective taking by reorienting the focal point from which systems concepts relate to a system and amongst themselves.

2.2. Human activity systems

System principles apply to human activity systems as follows:

1. Human activity systems have parts
    1.1. The parts can be conceptual or concrete
    1.2. The parts interrelate to produce persistent structures, processes, and meanings
    1.3. The parts' interrelations are conditioned by the kind, capability, and structure of the human activity system

Hillary Sillito states that a system is "a persistent region of low entropy (= high organisation) in physical or conceptual space-time". Then, it would follow that "systemness is the phenomenon that allows regions of organisation to persist in a dissipative universe" [4]. This applies to both main types of systems: concrete and conceptual. Concrete systems exhibit causal powers through physical structures and/or processes. We can design for systems that will maintain a structure, such as a bridge or a fuselage, as well as for systems that maintain processes, such as machines, software, etc. Conceptual systems exhibit persisting meaning, which is often related to models about real world systems. In systems engineering practice, however, engineers deal in a daily basis with a special kind of conceptual systems as we form teams and interact with colleagues while belonging and acting within the culture of an organization. Yet, the influence that conceptual systems have on our practice and the influence that our practices have on these special kinds of conceptual systems are often ignored.

Successful human activity systems are stable systems with low entropy that maintain their progression along a trajectory to achieve their goals. They maintain homeorhesic control towards fulfilling their purpose while maintaining a homeostatic state when 1) their purpose is well understood and 2) the causal powers needed to conduct purposeful activities are present.

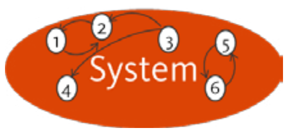

Fig. 1. System and its parts.

Human activity systems have interrelationships between concrete and conceptual parts that exhibit persistent structures, processes and meanings. Parts' interrelations are conditioned by the kind, capability, and structure of the human activity system. Note that in turn the kind, capability, and structure of the system are influenced by the parts' interactions, and these interactions depend on their degree of concreteness vs. degree of abstractness

2.3. Purpose

Human activity systems relate to purpose in accordance with the following principles:

2. Human activity systems exist to fulfill a purpose or a set of purposes
   - 2.1. Human activity systems possess inherent causal powers to fulfill their purpose
   - 2.2. The human activity system design is commensurate with its purpose
   - 2.3. Human activity systems are aware of their purposes, and pursue them intentionally

While other kinds of systems can also have meanings, functions and/or purposes, human activity systems are a special kind of system that intentionally pursues its purpose or set of purposes. Human activity systems form when humans perform activities with a purpose in mind [12]; for instance, a person typing an email in order to communicate an idea to another person. Purpose dominates the motivation of humans, delimits the human activity system's causal powers, and provides a measure for success [13]. Having a purpose influences what the human activity system is capable of by 1) guiding behavior and resource allocation, 2) delimiting a system's capability and structure, and 3) acting as a constraining agent to the potential emergence. Therefore, a human activity system must be carefully designed so that its kind and capability will be commensurate with its purpose, and so as to maximize its causal powers for pursuing its given purpose.

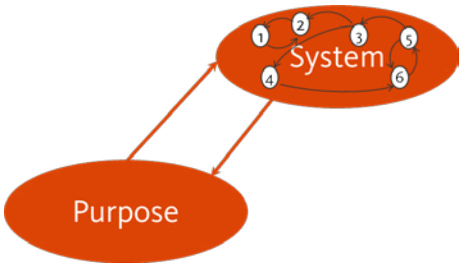

Fig. 2. The relationship between purpose and the other parts of the system.

Human activity systems are purposeful because they intentionally pursue their purpose and possess inherent causal powers to fulfill a purpose or set of purposes which implies that a human activity system kind, capability, and structure must be commensurate with its purpose. Commensurability is established by the balancing relationships shown by the arrows that connect system and purpose.

2.4. Boundaries

The boundary of a human activity system conforms to the following system principles:

3. A system mediates its interactions with its environment through its boundary
   - 3.1 A system submerges to its environment
   - 3.2 A system influences its environment

While Bertalanffy [14] characterized systems as open or closed, in practice those attributions are relative and theoretical in nature. Thinking about open and closed systems is useful when conceptualizing real life systems because it offers conceptual tools to assist SE endeavors. In practice, boundaries are open or closed within a spectrum depending on scale and context and are rarely absolute – an exception is the universe as a total system, which is a closed system. The notion of systems openness – or closedness – is particularly useful when human activity systems are concerned, as human activity systems never operate in isolation. They always occur within macrosystems, and information exchanges within and amongst them need to be considered in their design.

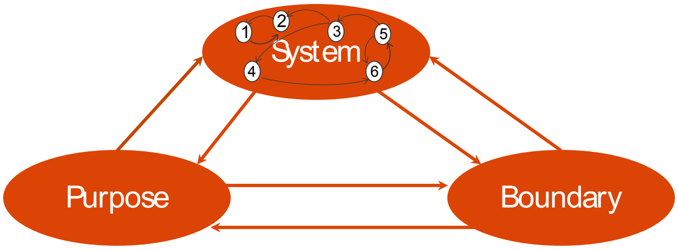

Fig. 3. Relationship between boundary, purpose and other parts of the system.

A system interacts with its environment, a higher-order system, by submerging to it and influencing it. Therefore, a human activity system must be carefully designed so that its kind, capability, and structure are not only commensurate with its purpose but also with the consequent properties of the boundary that mediates its relationship with its environment.

2.5. Relationships

The relationships relevant to a human activity system conforms to the following system principles:

4. Context and language modulate the relationships in a human activity system
   - 4.1 The magnitude and kind of the two-way relationships between the parts of the system, purpose, and boundary vary according to the context
   - 4.2 The magnitude and kind of the two-way relationships between the parts of the system, purpose, and boundary are conditioned by the language used.

In Figures 2 and 3 we have established that there is a two-way relationship potential between the parts of the system and its purpose and between the boundary and the parts of the system. In addition, there is a two-way relationship between the human activity purpose and the boundary. In an activity system, its parts (e.g. humans, machines, software) interrelate among themselves, but also with their purpose and boundaries. These relationships give rise to a system's structure but are also delimited by the parts' capabilities and the environment they are embedded. Therefore, the human activity system needs to be designed such that the kinds and magnitudes of the consequent relationships are commensurate with the purpose, boundaries and capabilities of the system and its parts.

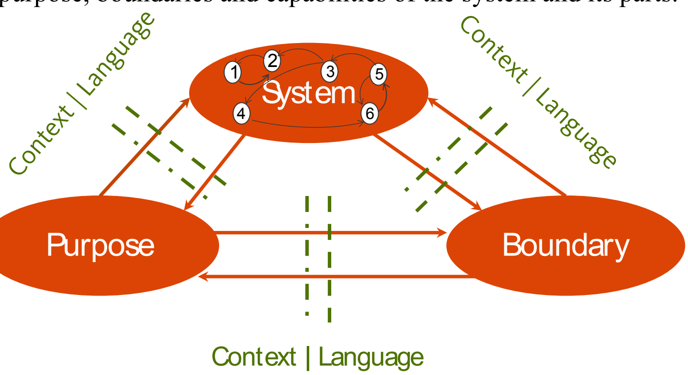

Fig. 4. Human activity system: emergence from purpose, boundaries, relationships, and context.

Regardless of the kind, capability, structure, purpose and boundaries, the meaning of a human activity system can be different to different stakeholders depending on their interpretation of the context and their linguistic proficiency. The context determines the morality of the purposeful activity [13], having an impact on the two-way explanatory arrows by determining the magnitude of the influence that purpose has on the parts of the system and on its environment. A similar process occurs between the parts of the system and the boundary and between the purpose and the boundary. Likewise, the degree to which the language adopted to control information flow within the human activity system is understood by all the parts of the system affects the nature of the two-way relationships depicted in Figure 4. This is an isomorphic process to that proposed by Kittelman, Calvo-Amodio and Martinez León [15] where the focus is on minimizing the gap between the conveyance of information by the sender and the convergence of information by the receiver. In other words, when there is no unified technical knowledge then the linguistic terms used by different stakeholders might be related to different concepts and even definitions.

3. Application example

In this section we provide an example based on a hypothetical small system design team. The team is charged with designing a multipurpose and modular high-tech widget. The organization is structured as a loosely-coupled organic network, with design decision authority given to teams when teams contain experienced engineers. Computers, white boards, design software and dedicated office space are provided. Table 2 provides an example of application of the human activity system principles we provide in this paper. The scope of Table 2 exemplifies the initial stage of the human activity system design. Here the principles are used to identify and/or characterize all the elements the design must specifically and objectively take into consideration in order to ensure an optimal balance between purpose and capability in the given context.

Table 2. Human Activity System Example

Component	Relevant Principle	Design Elements and Actions
System	1. Human activity systems have parts	
	1.1. Th’alighn top left’alighn centre left’e parts can be conceptual or concrete	Concrete parts: People, computers, software, furniture, whiteboards, etc.
		Conceptual parts: Beliefs, theories, perceived value of work, organizational culture, camaraderie, etc.
	1.2. The parts interrelate to produce persistent structures, processes, and meanings of the human activity system	Persistent structures: computer vs. user interaction, user interfaces, office layout, furniture, etc.
		Persistent processes: communication, design process followed, decision making process, regulations, etc.
		Persistent meanings: perceived value of work, organizational culture, team camaraderie, theoretical foundations used, etc.
	1.3. The parts interrelations are conditioned by the kind, capability, and structure of the human activity system	System kind: in-person, interdisciplinary, multimedia environment (computer, whiteboards, etc.)
		System capability: level of expertise, technical knowledge, technology available, etc.
		Parts interrelations: social and concrete networks and communication channels
Purpose	2. Human activity systems exist to fulfill a purpose or a set of purposes	Purpose: design a multipurpose and modular high-tech widget.
	2.1. Human activity systems possess inherent causal powers to fulfill their purpose	Causal powers: technology, knowledge, and design decision authority are present.
	2.2. The human activity system design is commensurate with its purpose	Commensurability of purpose: Experienced engineers possess sufficient experience to make design decisions; technology provided assist decision making.
	2.3. Human activity systems are aware of their purposes, and pursue them intentionally	Purpose awareness: purpose of team is communicated clearly and acknowledged by team.

Table 2. Human Activity System Example

Component	Relevant Principle	Design Elements and Actions
Boundary	3. A system mediates its interactions with its environment through its boundary	Concrete boundaries: beyond people involved; servers hosting software and data, office walls.
		Conceptual boundaries: repository of knowledge, organization team belongingness, etc.
	3.1. A system submerges to its environment	Submergence: team members focus on task and role at hand. Other roles and tasks are formally suspended while working with team.
	3.2. A system influences its environment	Environment: if modifications to decision making processes are found, experience engineers can enact changes in organizational procedures and regulations.
Relationships	4. Context and language modulate the relationships in a human activity system	
	4.1. The magnitude and kind of the two-way relationships between the parts of the system, purpose, and boundary vary according to the context	Context: The organizational structure is a loosely-coupled organic network, where each team possesses freedom and flexibility to organize and disband.
	4.2. The magnitude and kind of the two-way relationships between the parts of the system, purpose, and boundary are attenuated by the language used.	Language: being a transdisciplinary team, team members are not accustomed to each other's technical terminology, complicating effectiveness of interrelations between members, their boundaries, and pursue of purpose.

4. Conclusions and prospects

In this manuscript, we responded to the perception many engineers have that it is not practical to accurately model human activity systems and their evolution, but that an intuitive approach to designing such systems is nevertheless adequate. We disagree with such views, and argued that the unfolding of the fourth industrial revolution will require the application of principled methodologies for human activity system design. Without this, human activity systems will not be able to adaptively sustain a robust ability to pursue and achieve their purpose.

We have presented the foundational concepts and a set of systems principles for developing such a system model and design methodology, by integrating systems thinking and scientific systems principles in this context. We believe it is practical to develop a robust model to guide the design and monitor the evolution of human activity systems. It is worth noting that we have already applied this model in our human activity systems' management practice and it appears to us to be useful and capable of further refinement.

The significance of this development for systems engineering is that systems engineers have a starting point to begin answering the call, put forth by INCOSE Vision 2025 [1], for the development of engineering systems that can robustly deliver value despite the rising complexity of the demanded engineered systems. Nevertheless, it is worth cautioning the reader that the work presented in this manuscript is a limited and simple start. Much remains to be done to evolve, validate, and formalize the model and principles presented.

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