Handling Adaptive Complexity through Intermediate Developmental Cognitive Structures: Applications of Cognitive Complexity in Organizations

Gary Berg-Cross
Knowledge Strategies, Potomac MD
gbergcross@yahoo.com

Background

This paper grows out of several ideas of which organizational complexity, emergence, consillient synthesis and cognitive development are prime. The context for discussion is the observation that management and organizations are dynamic, cognitive systems that challenge both integrated sciences and their applied aspects such as Organizational Psychology and Management Science. Organizational complexity involves multiple agents interacting in such a way that as Axelrod (1999), Holland (1995), and Kelly &Allison. (1999) variously discuss it, hints of structure may appear. Following Holland (1995) we call these systems of multiple actions and reactions "Complex Adaptive Systems "(CAS). Simply put, a CAS is made up of smaller components with complex interactions and changing rules for interaction as time progresses. Interactions are rich and there are often multiple feedback loops in the interactions so that system history matters. This is one of the three key principles CAS behavior and evolution based on:

1. order is emergent as opposed to predetermined,
2. the system's history is irreversible, and
3. the system's future is often unpredictable.

As a dynamic system what goes on at a moment in time within a CAS is partly a function of what went on before, but this is so complex as to be often unpredictable. Intelligent components having substantial memory resources respond to information with more rules than non-intelligent. For example, when the components are intelligent agents within the system they operate under a set of rules that change over time as agents gain "experience" through encounters with the environment and with each other. As agents interact and their rules evolve, order "emerges" and patterns of behavior become evident. From this point of view the study of complexity suggests the importance of the study of how "stable" but flexible order emerges from the interactions among agents. This phenomena seems particularly evident in the development of children's cognitive abilities which seem to have a series of adaptive, intermediate stable points that build higher and more flexible levels of cognition. My hunch is that incorporating some of these simple adaptive strategies will be helpful in improving our science and its application.

The CAS paradigm can be used to study events on a small scale, such as the interaction of neurons or the development of the human immune system, but also on much larger scales, such as human interactions in organizations and culture (Anderson, 1999) , human interaction with climate, as well as the evolution of ecosystems. In this model an organization is a CAS and should recognize as such by organizations for several reasons:

- Not get stuck in inappropriate models and their approaches (local minimums)

- So it can develop more appropriate mechanisms for understanding the source and level of complexity it will face in the future.
    - For example organizations like other systems perform in regular, predictable ways but under other conditions they exhibit behavior that surprise us with its unpredictability. Seemingly small, undetectable differences in initial conditions is hypothesized lead to gradually diverging system reactions until eventually the evolution of behavior is quite dissimilar.
- So it can avail itself of emerging techniques and models

Before further considering such issues I want to expand the scope of analysis and motivation to that of Science as a whole. The study of complexity larger has grown out of analysis but there is an important component of complexity found primarily in synthesis. For example, take the sociobiologist E.O. Wilson's view of a scientific knowledge continuum presented in Consilience (Wilson, 1999). In this view the central question for scholars is whether all of knowledge is intrinsically consilient, which Wislson defines as "whether it can be united by a continuous skein of cause-and-effect explanation and across levels of increasingly complex organization." The problem Wilson argues, lies in the recognition that the traditional line separating the great professional branches of learning (natural sciences, social sciences, and humanities) is less a clear barrier, than a broad domain of poorly explored material phenomena which we are only beginning to explore cooperatively. We are all familiar with the basic, "professional" science hierarchy with physics as a foundation, chemistry at the next level, followed by biology and then the branches of social sciences. Each branch of knowledge studies a subset of an assumed common reality (a tenet of "naturalist philosophy") that is intrinsically interconnected with all the other branches. Physics studies the most basic forces and the smallest "units" (which may or may not be "particles"). Chemistry studies the properties seemingly emergent from interactions between these of chemical units. Biology studies properties emergent from still higher interaction of chemical dynamics in structures like cells. Psychology, sociology, economics, and anthropology study emergent properties from the interaction of human units and organizational units.

In large part, following the Enlightenment, scholarship has successfully interlocking several aspects of theory in the hard sciences. That is, the relationships between physics, chemistry, and biology are workably well-defined and seem to be converging. When we get to the relationship between biology and say, psychology, it represents a frontier of useful exploration, especially in the fields of cognitive and behavioral neuroscience. While each new level produces properties unique to that level, complexity science finds some similarities exist between the various levels which further integrates theory. At the very least, someone studying a field like Cognitive Psychology can learn much by examining how the units at the next lower level (Neuroscience, Biology) work and how the units they study influence dynamics at the "next level up". Also, Science should not practically propose a higher level if it did not make some real difference in prediction about how a lower level unit will function in its presence. Complexity theorists argue strongly for emergent factors at each level and indeed the development of complexity through emergence.

One of Wilson's basic points is that an integration between levels is necessary to advance us at this stage of our science and this integration is somewhat stalled at the level between Biology and Social Science. One reason may be that prior efforts have ignored the dynamic, adaptive and emergent aspects of social systems, which make it's core more non-linear so that many of our techniques borrowed from the earlier phase of the hard sciences break down when applied to the Social Science realm where we would like to understand complex phenomena for our benefit. In the continuum of sciences as dynamic systems, the idea is to look for repeatable "patterns". The prototype of these were linear patterns, but now we are struggling with non-linear ones. Once patterns are found scientists unify these patterns by synthesizing a theory. The science of complexity is now arguing that a higher similarity of pattern has been found in these patterns as CASes rather than linear systems. For example, going from the top down: the behavior of a collection of agent producer/consumers in an "economy" is similar to the behavior of a collection of agent predator/prey in ecosystems, which in turn is similar to the behavior of a collection of agent neurons in a CNS etc. So a CAS-oriented consilient approach may attempt to study and discuss these systems using their adaptive commonalities within an agent framework. Studying systems as collections of agents may help us to come up with a unifying, consilient theory with similar patterns at each level[1]. Part of the similarity may be emergent properties, which are not well understood in traditional views of organizations. Cognitive Psychology represents a border area between the hard and softer sciences and some of the approaches used there may help provide bridge ideas for the social science and its application in organizations. These ideas are considered in the next section, following which a developmental, emergent view is discussed.

Information Processing and Adaptive Organizations

For a long time modern organizations have been viewed through a mechanical, linear focus using Newtonian ideas of command and control, along with prediction and planning. This is particularly true in terms of expectations about how an organization should go about its tasks of resource management and outcomes evaluation. In the world of health care, where I have consulted, the vision and implied mental model of a carefully managed organization is of well-oiled machine where "fat" is cut out of the system, incentives are aligned, and competition drives all actors to ultimate efficient and effective behavior. Derivatives of this is still often called "best practices" although evidence of the success of management strategies based on this mental model is scant at best (Anderson & McDaniel, 2000). A more modern concept is the organization as a rational information processing entity as shown in Figure 1 (March and Simon, 1958). In the IP model action is not generated directly by perception, but is mediated by cognitive mechanisms leading to behavior generation. Central information processing uses "World Model" knowledge[2] that works like a de-coupling module between perception and action. This model builds on the ubiquitous cognitive idea of a "rational agent' using a centralized store of 'knowledge' to 'succeed' in the world through planned actions accomplishing goals[3].

---

[1] Later in the paper I suggest a cognitive pattern that helps understand some of these issues from a rational-pragmatic model.

2 Newell treats knowledge as a function of rationality "Whatever can be ascribed to an agent such that its behavior can be computed according to the principle of rationality."

[3] In decision theory an agent is rational if and only if it chooses the actions that yields the highest expected utility, averaged over all possible outcomes of actions - Maximum Expected Utility

EU(a | E) = Σ i **P**(Resi(a) | E, Do(a)) x **U**(Resi(a))

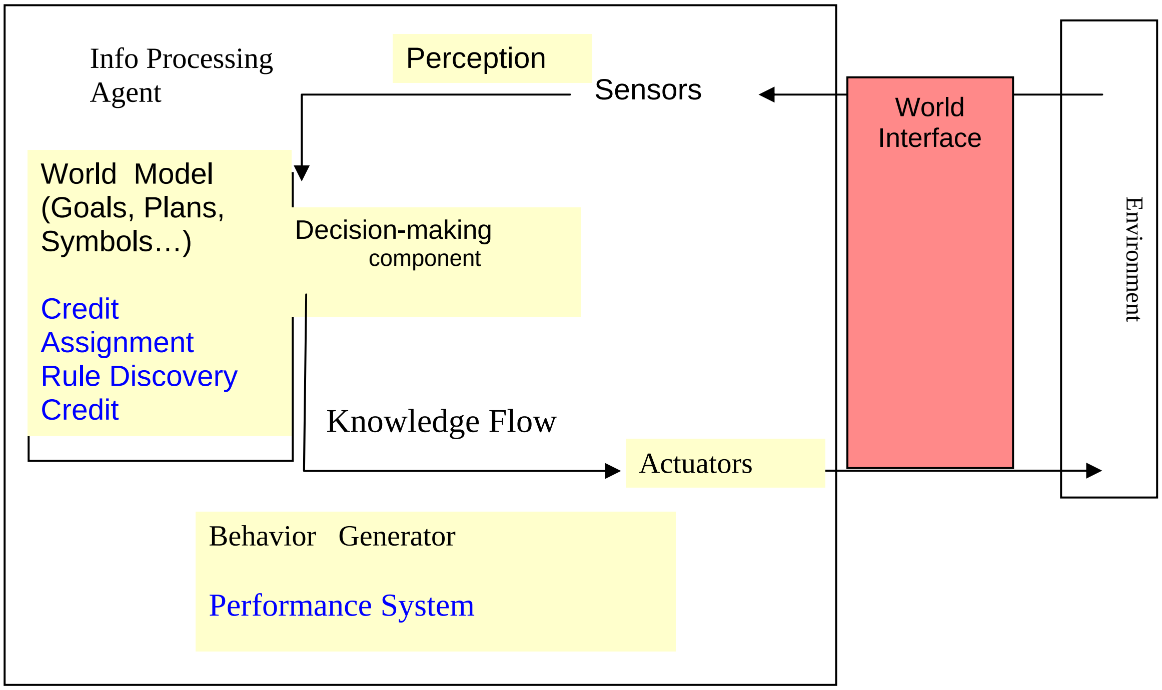

Figure 1 The Sense, Think, Do Cycle of Information Processing

Rational agents are those that perform rational actions which means doing the "right" action In turn the "right" action is one that will move an agent towards a goal and makes the agent more successful (Simon 1978). In the Carnegie Mellon 'decision making' school of management a starting assumption is that individual agents are subject to cognitive limitations so that they behave with "bounded rationality" when making decisions. That is, due to processing and memory limitations agents construct a simplified model of the complex real world based on partial information. As bounded, rational beings they satisfice rather than maximize by looking for a course of action that is 'good enough' rather than the best possible (Simon 1957). Theories are then put forth on how these cognitive limits may be overcome, largely through formal and informal organizational structural mechanisms. Simon argued that organizations make it possible to make decisions because they constrain the set of alternatives to be considered and the considerations that are to be treated as relevant. Organizations can be improved by improving the ways in which the limits on rationality are defined and imposed. This IP model of organizational decision making is characterized by these activities: sequential search ('one thing at a time' approach), the activation of predefined action programs, (March and Simon 1958), the quasi-resolution of conflict, and the avoidance of uncertainty (Cyert and March 1963).

An information model of organizations tries to provide a theoretical framework for analyzing such things as:

- the information needs of an organization,
- the processes by which information is acquired and utilized, and
- the goals, plans and purposes which underlie the use of information.

By concentrating on the information-use behavior of organizations, this perspective has helped application of information technology and information systems in organizations which has becomes central in modern business. Management research has used an IP approach to analyze how an organization searches for information to decide alternative courses of action, to help design an efficient organizational structure, and to model the processes by which an organization creates a shared interpretation of its environment.

The IP model is modular and offers more flexibility but there are problems with it both at he individual rational agent level as at the organizational level. As we have rationalize business with IP models, systems and management we may have lead to some emergent complexity. Certainly many of our business modernization efforts have failed. The traditional organizational management model emphasizes convergence and compliance to achieve pre-specified organizational goals. IT/IP management systems were modeled on the same paradigm to ensure adherence to organizational routines built into information technology. Such optimization-based routinization of organizational goals with the objective of realizing greater efficiencies assumes relatively stable and predictable environment which has proven increasingly inadequate in the face of arms-race like business competition and discontinuous environments driven by technology innovation. As discussed in Berg-Cross (2003) the situation is a bit Ptolemaic. That is, we have some simple processes and a reductionist, nature as particles philosophy with some simple "circular-like" processes. In the current system of cycles and epicycles we have certain perfect cognitive process as the functional/circular primitives that we are willing to accept as heuristic devices for their immediate computational usefulness. Core functions are added all to in an ad hoc way as required to obtain any desired degree of performance and accuracy when we are surprised by "emergent" phenomena. A paradigm shift to a CAS approach may not only explain divergent observations but make fellow scientists look at the world in a more integrated, consilient way.

Simply stated the attempt to structure functional models that manifest intelligent behavior leads to an explosion of modules, the interaction of which quickly leads to complexity. For example problems include a sequentializing problem with components due to the highly interactive nature of functions e.g. perception-motor interactions. Also "Knowledge" and its grounding seems to be/mean very different things (different representations) in different parts of the "cycle" which leads to knowledge translation/integration problem. And knowledge doesn't occur in a big bang, it is more typically an incremental, evolutionary affair. Concepts and conceptual knowledge are fluid, influenced by beliefs, hypotheses, context, and experience and the traditional IP approach seems to miss these factors. With some tuning we can enhance the IP model to see adaptive agent functioning made of 3 components:

- a performance system (in organizations a "capability" to accomplish objectives)
- a credit-assignment method (organizational reward systems
- a rule-discovery method (business reformulation and innovation)

The performance system is essentially most of the IP model and consists of a set of detectors (which perceive the environment in terms of stimuli) and a set of IF/THEN rules (e.g. internal schema), that can firs a set of effectors determining the behavior of the agent. The credit-assignment method provides a basis for learning by strengthening those rules which make for rewarding behavior. Suitably implemented it also provides an agent with hypotheses that anticipate future consequences. Together these introduce adaptation. Rule “discovery” provides for new rules. Specifically, it provides for new plausible rules. Taken as a whole, an adaptive agent is a type of rational IP agent with the ability to strengthen those rules which "work" best, and the ability discover new plausible and possibly "better" rules.

The new business ecology emphasizes continual reassessment of business processes that are more intimately integrated with organizational decision-making processes. Alignment is also emphasized, for example, key practices, IT systems and working assumptions are aligned with infrastructure investment and environment. The strict IP/IM approach has blended in a knowledge management (KM) approach attempts to capture key knowledge and make it available to ensure that effectiveness of decision-making (doing the right things) is not sacrificed a bottom line of increased efficiencies (doing things right). A knowledge management focus has made some attempts to balance and soften naive optimization approaches of IP management (and its systems) with the more divergence ideas of communities of interest knowledge based organizational experience. In my opinion the lack of success of KM, like IM/IP approaches lies in an overly simplistic model of knowledge, knowing and adaptive processes of organizational intelligence. That is, the dominant conception of IT enabled knowledge management is constrained by the fundamental nature of the knowledge creation processes. The real world is continuous, dynamic and unpredictable with no uniquely defined states. Our knowledge and models are therefore uncertain and incomplete. Current KM notions, used to institutionalize knowledge in systems, has largely ignored the open, tacit, dynamic, experiential, interpretative and evolutionary nature of knowledge. This is a CAS view still using internal models, hierarchies of building blocks and aggregation ideas of prior work but adding dynamic nonlinearity and diversity in the spirit of Consilience.

A more adequate basis for understanding human and organizational intelligence is that it emerges as an adaptation from an interrelated network of automatic, deliberative and belief-based cognitive processes serving, adapted functional goals. Such embodied architectures are beyond the traditional scope of engineering which attempts to decompose functions using mechanistic principles. Key aspects of a new CAS type model include:

- a commitment to a rational-empirical view of intelligence, reasoning & knowledge
- Realization that propositional representations are not primary knowledge but an ingredient which becomes knowledge via interpretation. Thus, there is a relation between propositions and the system of <u>beliefs</u> that cognitive agents know/use in organizations
- Evolutionary factors and lower unit-based enabling structures means that agent knowledge is a fluid, inconsistent mix of approximate facts, hypotheses, goals and concepts. This well described by Sowa’s Empirical-Rational Knowledge Cycle (2000) based on Charles Peirce’s pragmatic philosophy (See Berg-Cross, 2003).

In the remainder of the paper I will illustrate a framework using a biological, developmental perspective to discuss the scruffy, but rationally organized adaptive nature of intelligence as we see it in people and organizational systems.

A Rational Architecture for Integrated Cognition

Berg-Cross (2002, 2003) proposed a three-part architecture (shown in Figure 2) that expands upon the typical IP view to provide a more dynamic view of cognition. At the lowest part of Figure 2 we have situated-reactive processes. In individuals these represent automated responses time tested by evolution. In organizations these represent some core processes attached to relatively invariant aspects of the environment. This part also provides factual input to middle, goal-based planning level which may be considered the type of IP/KM process previously discussed. Both levels are needed for intelligent behavior. Goals and plans provide stability via intentional control and strategic guidance. These coordinate and package action-schema responses. With experience dynamic interactions between these levels are shaped by feedback from the environment. There is a top level for belief-desire-intention (BDI) driven processes which provides further stability (via things like activation pattern attractors) for the other levels based on belief models. An interesting line of psychological work suggests some direction for research into corresponding top-down processes, such as proposed in the 3 part reference architecture of Berg-Cross (2003). Gergely et al (1995) have proposed a theory of the one-year olds 'naïve theory of rational action' based on evidence for causal and other beliefs such as are hypothesized as belief-desire-intention processes. Infants seem to "comprehend" a goal-oriented aspect of agent behaviour of agents. This is also seen in declarative pointing which is characterized by coordination of an extended arm and index finger intended to draw attention to a distant object. Unlike other pointing, it is not necessarily a request for an object. Instead children often use declarative pointing to draw attention to objects clearly outside their reach (e.g. a passing cat). Further, declarative pointing only occurs under specific social conditions; children do not point unless there is someone to observe their action. Other research on children's attentional responses (using habituation) shows that they take

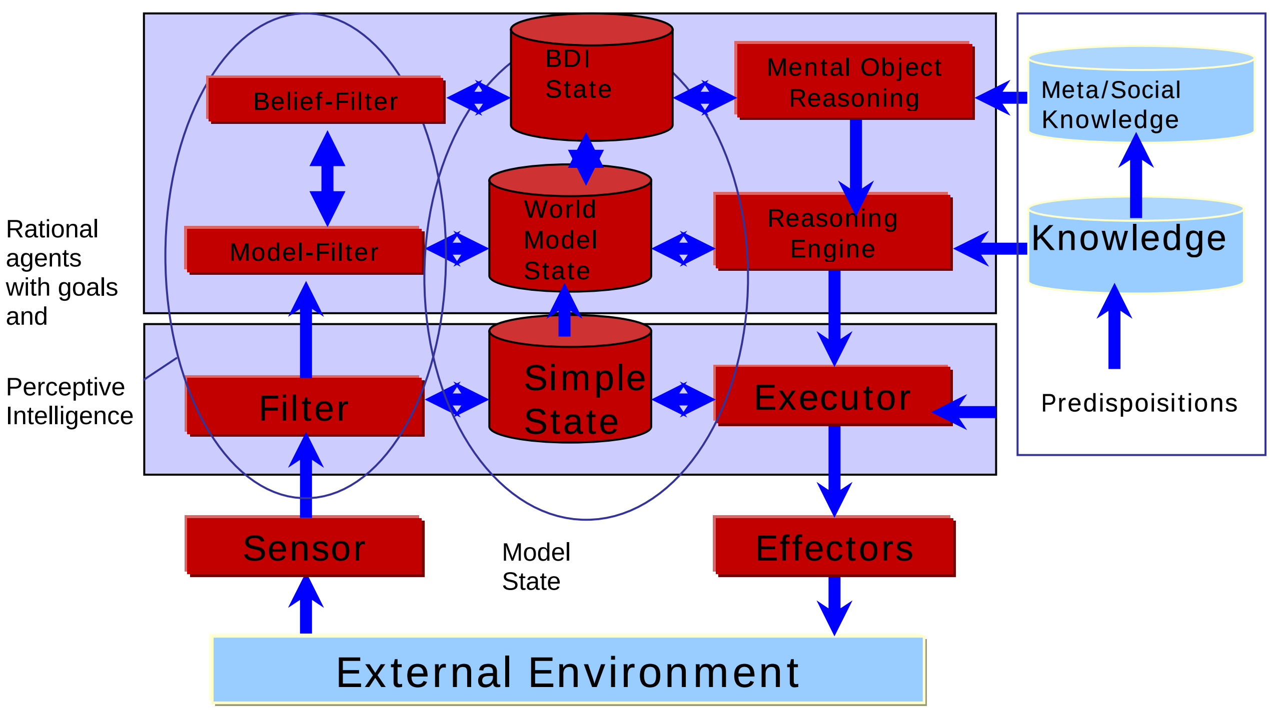

Figure 2 A hybrid Model of Intelligence

goals into account and anticipate future actions in coordination with these goals. For example, evidence of "teleological" interpretation by a 1 year old can seen in their attributions of agent desires (e.g. to drink water) as an explanation of an abstract figure's jumping action over an obstacle. Controlled studies also show child beliefs (e.g. there is juice in a bottle). Thus, there is developmental evidence for an early interpretive understanding of others as psychological (intentional) agents whose actions are related to goals and desires.

We can hypothesize that the rules of interaction between the "units" of our 3-level model provide a substantial degree of the emergent complexity in intelligent systems. Note, that this system looks hierarchical and is easily discusses as such but is not strictly hierarchical in operations due to differing areas of control and timeframes for response. This is clearly seen in child development where a range of data provides evidence for the development of early proto-rationality and approximate knowledge. A good way to explore such properties may be to consider the emergence of intelligence in human children. It's well studied, but still challenging and falls in the border area between Biology and Psychology. Returning to the idea of integrated science Wilson (2000) sees a key to necessary bridge-building as the discovery and analysis of human nature, which he argues consists of the epigenetic rules—interactionist regularities in mental development now well under way, at the biological, social science, and humanities levels[4]. These can be researched borrowing ideas from developmental psychology approaches – for example, from Piagetian/neo-Piagetian ideas of emergence and self organization in development. As development proceeds in a child behavior becomes more organized through the complexes of dynamic interactions between individuals and environments, and among processes and subsystems (Smith and Thelen 1993). In Piagetian terms we may decribe a fluid model of knowledge which starts as physical schemata (see Figure below for a notional ideas of schema and dynamics), extends to other physical examples of a phenomena in the service of goals and beliefs. Knowledge, as we first see it manifest in children's actions, are often tentative and prove less than optimum for situations and are thus highly modifiable. While adult knowledge seems less tentative it is more approximate than logical as implied in the dynamics of our 3-part model. Given this, it seems useful to consider intelligent performance as part of a dynamic system in which agents and their

[4] Wilson's examples of epigenetic rules include the origin of color vocabularies, incest avoidance, optimum arousal in artistic design, and response to the natural environment.

Representing Schema and Dynamics

An extensive treatment of how to apply dynamic systems modeling to cognitive and language development can be found in van Geert (1991).

Language development **L** (cognitive growth in general) consists of growth which is not entirely caused by some external factor (autocatalytic). This growth is caused by the system itself, i.e. change is induced by the cognitive system itself. In the case of finite verbs, the growth of finite verbs is, for instance, not induced by the development of verbs in the input (the parents), but it is due to the structure of the system (i.e. language) itself.

The process depends on several factors some of which is shown in the equation below:

$$L = L + L * (r - r * L / K)$$

K =carrying capacity
r = a growth rate.

Representations are also dynamic and relate to our 3-part architecture

Level 1 Early stage physical schema as reflex = f (s,$m_{reflext}$)
Level 1, 2 interaction integrated schema = f (s, Goal Plan, m_{plan})
Level 1,2,3 Belief-based plan = f (s, Belief, Goal Plan, $m_{belief\text{-}plan}$)

environment join forces over time creating "development" such as language growth. A consilience-like convergence of data and theory from genetics, embryology, and developmental biology suggests to many the possibility of a more epigenetic, contingent, and dynamic view of how organisms develop. Thus, the fundamental unit of analysis in the psychology of behavior isn't the human individual or any subsystem of that individual, but is interactional. The dynamic patterns of agent development, and how they achieve stability, are similar to and usefully to understand adaptive emergence at higher levels such as with organizations.

Developmental Dynamics, the Rational Empirical Cycle and Intermediate Stages

A study of developmental dynamics of intelligence could reveal how underlying cognitive mechanisms unfold over time and provide insights that are complementary to, not mutually exclusive with, the functional explanations already provided by linear approaches. This has now begun to be studied using "epigenetic robots" designed using Piagetian ideas of development. Lickliter & Honeycutt (2003), for example, describe the view of development as a self-organizing, probabilistic process in which order and pattern emerge to change as a result of transactions among developmentally relevant resources both internal and external to the organism. In this dynamic view it is more accurate to say that development results from and bidirectional and dynamic transaction of lower units (genes, cells, tissues, organs, organisms etc.) during the course of individual ontogeny. Lickliter & Honeycutt's (2003) argue that a study of developmental dynamics could reveal how underlying mechanisms unfold over time. This has now begun to be studied using "developmental robots" designed using epigenetic ideas of development. When applying these ideas to the development of intelligence such formulations parallels that of Piaget's (1950) views on adaptation to the environment. Piaget's theory of children's intelligence describes it as construction of mental organizations, realized as the evolution of schemas previously described. These are used to represent the world and designate action but also beliefs and goals. This adaptation is driven by a biological drive to obtain balance between schemes and the environment (equilibration).

This developmental path to intelligence provides a substantial set of intermediate knowledge products for an agent. By Piaget's account, the sensori-motor stage in biological systems is a structured process, where sensing mechanisms are gradually integrated with motor actuating mechanisms on the developmental path to a mature performing system. For human babies this takes 2 years. The first four months organize a substrate of reflexive responses into more coherent motor strategies called physical schemas. These scruffy structures are proposed as the basis on which more abstract knowledge is built. In addition sensory modalities are coordinated and attentional mechanisms begin to emerge – all satisficing environmental constraints and inherited motivators which are realized in a series of intermediate forms on the path to adult structures. From four to six months, reactions are "practiced" until an infant exhibits what seems like intentional prolonging of special interactions. In Piagetian terms stable agent-world interactions patterns emerge that are evidence of satisficing, temporary cognitive structure built in a bottom up fashion. These are initially constructed as physical schemata, but may be used by an agent to handle other instances of this type of interaction. Studies of infant behavior suggest that its not all bottom up, schema are increasingly coordinated by plans and belief modeling such as describe by a Belief-Desire-Intention (BDI) agent model. Essentially a BDI model structures knowledge within an agent – in terms of beliefs, goals and plans – which simplifies actions, supports language learning and allows coordination between agents.

The American philosopher Charles Peirce developed what I find to be a useful framework to understand belief, and the relation of knowledge to pragmatic reasoning. Peirce's Rational-Empirical reasoning theory has been organized by Sowa (2000) into three parts as shown in Figure 3 below:

1. Induction or learning which start with observations and looks for commonalities (a basic cognitive process) deriving a theory to summarize observed data.
2. Deduction or inference which starts with a theory and observes some new data. Theory is then used to logically generate implications
3. Abduction or guessing which starts with disconnected observations and guesses (hypothesizes) a theory that relates them. The test of this hypothesis is by means of pragmatic tests using subsequent induction and deduction.[5]

These processes are organized into an overall system of (Figure 3) by Sowa using an additional idea - knowledge soup a metaphor for fluid knowledge and intermediate cognitive structures. Knowledge soup captures the idea that real human knowledge is not static but dynamic and lumpy, with adherable chunks of theories and hypotheses that float in and out of awareness. As knowledge circulates through this process it may connect to other items, become more coherent, gather new meanings, be validated by successful predictions. Empirical validation makes agent's model "better" in a practical, predictive sense by correspondence of the model(s) with reality. At it simplest, this model provides a better frame for knowledge corporate management approaches and a nice connection to iterative processes such as used in systems development. The process allows for a natural history of knowledge flowing from conjectures and theory to prediction and groundings in observations both at the formative and subsequent part. Taken together it structures Peirce's idea that the true meaning of any "product of the intellect" is what would impart to practical results under "any and every conceivable circumstance, supposing such conduct to be guided by reflexion carried to an ultimate limit."

---

[5] This provides a cognitive basis for scientific since the model of reasoning is the ones that natural science use..

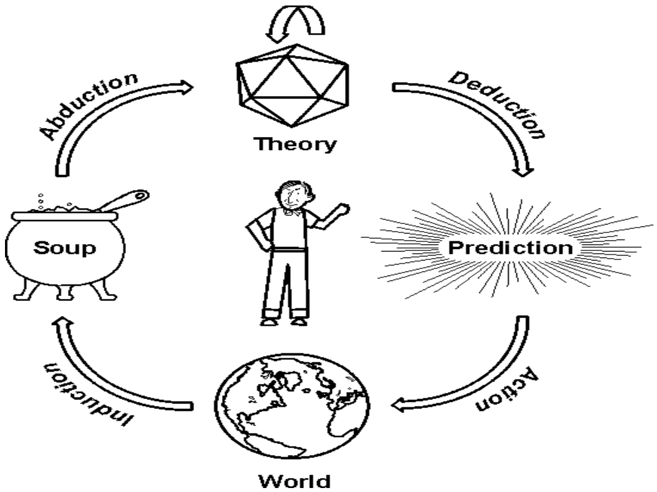

Figure 3 Sowa-Peirce's Rational-Empirical Reasoning Cycle

Figure 4 expands Sowa's discussion to further `illustrate relations between knowledge soup contents and the world. Reality stands on the left while on the far right is a lumpy part of our knowledge soup externally expressed as formal theory in represented in predicate calculus such as Peirce pioneered. As Johnson-Laird (2001) observed, brains do not use logic so much as they use "mental models". In the middle is more recent formulation of such a larger Tarski-

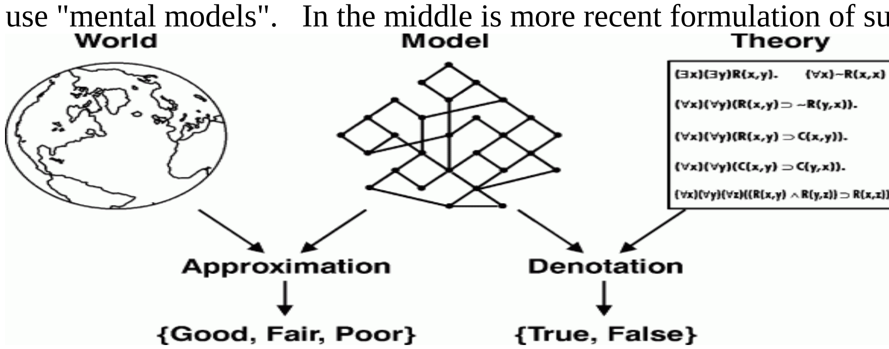

Figure 4 Denotation & Approximation Mappings between Models, Theory and Reality (Sowa 2000)

style model expressed by Sowa as a graph. World models are also part of our knowledge soup but their expression is more abstract and approximate. The figure represents a part of what we might call pragmatic model with knowing represented as a mapping from the symbols of the formal theory to vaguer symbols of the model. It is worth noting that the model shows that models are only a approximation of reality. Both are complex and our models increasingly. Models may be mathematized to show non-linear properties. Reality has these properties inherently. Sowa proposes that this mapping determines the denotation of propositions as having a binary {true, false} truth value. We might speak of these as our formal abductive hypotheses about the larger model. Even the symbols and logic chosen to represent these may be considered hypotheses of what will best represent the larger, soupy model.[6] The mapping from the model symbols to certain

---

[6] Sowa discuses written symbols as representing axioms of a theory, whose implications are some abstract set of propositions. Peirce might note the pragmatic semiotic nature of such mappings as part of the task to ascertain laws by which intelligence uses one sign to generate another, as "one thought brings forth another." Peirce saw pragmatic semiotics as the study that relates signs to

aspects of the world relates to the pragmatic adequacy of the model as an approximation designed and intended for some particular purpose. But agent purposes are endless and reflect the situatedness of our cognition so there is no simple, ultimate model. As a consequence when we express the central Tarskian model in formal mathematical structure we are forced to use some abstract simplifications of tokenized symbol types. These are tentative, preliminary, abductive hypotheses at a more abstract level.

Applications and Wrap Up

I started by pointing out deficiencies in isolated, linear approaches to cognition and its manifestation in organizations. From there I explored ideas growing out of cognitive theory, CAS concepts and pragmatic philosophy. A three part architecture was used to frame some dynamic issues and developmental concepts were used to explore some of these ideas. On the whole this has been metaphoric use of these concepts but it does suggest some things as we consider improving organizations and people. Anderson (1999) has already provided a useful analysis of implications of CAS on organizational functioning showing how complex organizational processes are affected by small changes. He outlines several dynamics that provide guidance for an organization's functioning. These include some normative observations:

1 dis-equilibrium is the norm,
2 external agents/environment drive the process,
3 complex processes have emergent properties that resist reductionism,
4 patterns emerge from simple rules, and
5 systems exhibit self organizing characteristics.

As Anderson observes, these principles have older roots in organizational theory - notably open systems theory, but complexity theory has added an emphasizes to the decentralized, adaptive, context-rich nature of organizations and organizational behavior (Anderson, 1999).
A key implication of organizational complexity theory is that managers and organizations that understand these dynamics will be better equipped to address failures that resist current management theory and practice including:

- Over reliance on naive Information Processing (IP) models which gives organizations too simplified a view information sharing which is based on a fixed knowledge concept

- Simplistic and inflexible use of top-goals and plans which leads toward mechanical management rather iterative processes based on approximate and adductive principles

=

- Mechanical management that is often too top down or bottom up but not integrated. A major example is Strategic Planning based on top-down thinking which doesn't engage the entire rational-empirical process. CAS models calls for more conscious organizational control and transformation processes in organization in order to deal with the inherent complexity (Dudik 2000).

---

agents who use them to refer to things in the world and to communicate their intentions about those things to other agents who may have similar or different intentions concerning the same or different things.

- Limited use of true knowledge management. Knowledge should be seen as part of a dynamic, rational-empirical system. Problems with linear methods of KM can be seen in the difficulty building enterprise models that integrate different levels of an organization. Entities mean different things at different levels and current methods may not allow very useful integration since with multiple levels there will be non-linear mapping of info between them.

References

Anderson, P. (1999) “Complexity Theory and Organization Science,” *Organization Science,* 10: 3: 216-232.

Anderson, R. A., & McDaniel, R. R. (2000). Managing healthcare organizations: Where professionalism meets complexity science. *Health Care Management Review 25*(1), 83-92.

Axelrod, R. and Cohen, M. (1999) *Harnessing Complexity : Organizational implications of a scientific frontier* The Free Press, New York, 1999

Berg-Cross, G., A Pragmatic Approach to Discussing Intelligence in Systems, presented at PerMIS 2003.

Cyert R.M. and J.G. March. 1963. *A behavioral theory of the firm.* Englewood Cliffs, NJ: Prentice Hall.

Dudik, E. (2000) *Strategic Renaissance*, Amacon, New York, 2000

Gergely, G., Nádasdy, Z., Csibra, G., & Bíró, S. (1995). Taking the intentional stance at 12 months of age. *Cognition, 56*, 165-193.

Holland, J. (1995) *Hidden Order: How adaptation builds complexity* Addison-Wesley, Reading Mass., 1995.

Kelly, S. and Allison, M.A. (1999) *The Complexity Advantage*, McGraw Hill, New York, 1999.

Lickliter, R., & Honeycutt, H. Developmental dynamics: Toward a biologically plausible evolutionary psychology. *Psychological Bulletin,* 2003 *129,* 819 – 835.

March, J. G. and H. A. Simon. 1958. *Organizations*. New York: John Wiley.

Simon, H.A. 1978. Rationality as a process and as product of thought. *American Economic Review* 68: 1 - 16.

Smith, Linda B. & Thelen, Esther Eds. *A Dynamic Systems Approach to Development*. Cambridge, MA: MIT Press. 1993. (xviii + 414 pp.) ISBN: 0-262-19333-7.

Sowa, John F. *Knowledge Representation: Logical, Philosophical, and Computational Foundations,* Brooks Cole Publishing, 2000.