Welcome to the Intelligence Age: an examination of intelligence as a complex venture emergent behavior

Linda J. Vandergriff
The Aerospace Corporation, Centreville, Virginia, USA

Abstract

Purpose – Aid knowledge management (KM) and business intelligence (BI) practitioners explore and exploit the Intelligence Age complex venture model focusing on intelligence as an emergent behavior. The paper aims to extend the discrete model used by classical system engineering (SE) for a wisdom, knowledge, information, data, and measurement (WKIDM) pyramid to add a wrapper of emergent intelligence to support successful decision making and implementation.

Design/methodology/approach – Building on previous theoretical complex venture work, this research explores the value of extending the WKIDM or "Knowledge Pyramid" model proposed by classical SE and KM approaches. The resultant IWKIDM model builds on the insights derived from chaos and complexity theories; KM research; observations of several acquisition successes and failures; and doctoral research on agile enterprise decision support.

Findings – The paper finds that successful classical SE complicated systems models built with the closed system assumptions of linearity, predictability, and context independence do not scale to the needed open system Intelligence Age solutions. It is necessary to build on a Complex Venture model that guides the engineering solutions that: leverage emergent behavior insights to develop an improved intelligence model for the interaction of complex venture intellectual capital (i.e., self-organizing agents) with the WKIDM pyramid entities and the intelligence products consumer context; and examine WKIDM pyramid levels of abstraction for detachable and complex representations (e.g., explicit versus tacit knowledge).

Originality/value – A complex venture conceptual model informs the architecture and systems engineering acquisition practices for new solution category to empower the venture's intellectual capital to produce needed emergent intelligence.

Keywords Systems engineering, Intellectual capital, Intelligence, Knowledge management

Paper type Viewpoint

Introduction

The human race has experienced several cultural ages, each marked by world view change. As the twenty-first century arrives, the closing of the Industrial Age gives rise to an era dubbed the Intelligence Age (Tyson, 1997)[1]. Many experts have identified that the new economy includes new sources of intelligence related wealth generation and is increasingly reliant on the free flow of intelligence-based products and services (Vandergriff, 2005; Waltz, 2003; Allee, 1998). Thus, as intelligence becomes a primary commodity, innovation, creativity, and ongoing learning are the currency of this new intelligence-based economy. The currency is a prerequisite for maintaining an organization's capacity for creating new, and updating the old expertise and core competencies (Waltz, 2003; Stewart, 2001; Bixler, 2000; Malhorta, 1998).

VINE: The journal of information and knowledge management systems
Vol. 38 No. 4, 2008
pp. 432-444

0305-5728
DOI 10.1108/03055720810917697

The new economy's rule set is changing significantly. The twenty-first century revolution is characterized by complex nonlinear emergent behaviors (Hamel, 2000). In order to understand and prosper in the Intelligence Age, organizations are required to change their basic world view or operational models[2] of the rapidly changing and volatile world. Care must be taken because outdated model assumptions can blind an organization to real world effects. One of the main "brutal facts" (Collins, 2001) of the Intelligence Age, is that an organization's context[3] has direct bearing on the organization's success. This means that an organization cannot be isolated from the multiplicity of market forces acting in a complex manner, producing non-predictable environments with emergent behaviors. Another brutal fact of the hypercompetition context (D'Aveni, 1994) is the "collapse of float" identified by Hock (1999), founder of Visa International. Before the world was so connected, concepts and things took time to travel. The knowledge about how to smelt iron took almost a century to cover the European continent, ushering in the Iron Age. Today, intelligence is available in minutes, if not seconds. Thus, IWKIDM float has virtually disappeared. Technology floats are minimal, with new technology adoption happening in months or days. With cultural floats, popular trends sweep across the world almost instantaneously. (Hoffman, 2002)

It has been recognized that having good business intelligence (BI) is vital, but significant false steps have been made and the return on investment (ROI) has been elusive. This is a result of using the old discrete, context independent models for intelligence generation, codification, transfer, and use. This paper addresses a new complex venture[4] operational model that embraces and leverages Intelligence Age complexity and the collapse of floats.

Discrete Data, Information, Knowledge, and Wisdom model overview

> Where is the Life we have lost in living?
> Where is the wisdom we have lost in knowledge?
> Where is the knowledge we have lost in information? (Eliot, 1934).

The first mention in literature of the relationship of wisdom, knowledge, and information is in the T.S. Eliot (1934) poem *The Rock*. Although used earlier the origins of the Data, Information, Knowledge, and Wisdom (DIKW) model are not traceable. Most KM sources cite Ackoff (1989) as the earliest reference to the DIKW hierarchy. He mentioned the hierarchy in his 1988 Presidential Address to International Society for General Systems Research (ISGSR).

Several representations (Martin, 2006; Bellinger *et al.*, 2004; Waltz, 2003; Weick, 1995) have been created to illustrate various aspects of the discrete Wisdom, Knowledge, Information, Data, and Measurement (WKIDM) model. Figure 1 combines the most common attributes described in the literature (Ullman, 2004; DAU, 2003; Vandergriff, 2001, Skyrme, 1998, Cho *et al.*, 1999). The pyramid implies that to achieve each level something is added and the volume is reduced. Thus, each level reflects intellectual capital with different processing and application levels.

Based on my dissertation work (Vandergriff, 2006), the WKIDM levels of abstraction are defined as:

- "Measurement" is defined as physical readings of phenomena from scientific instruments (e.g., photons) or event/object observations by individuals or groups.

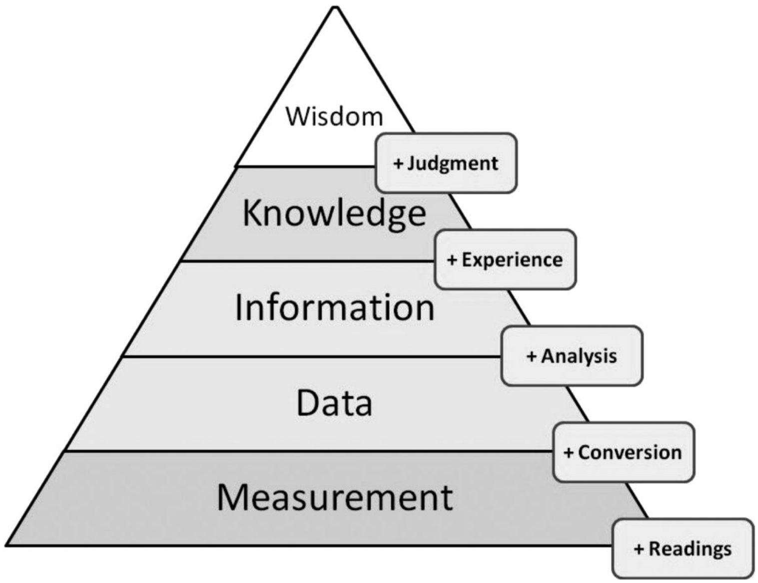

Figure 1.
Discrete WKIDM pyramid

- "Data" are the symbols, numbers, textual clauses, and other descriptive phrases or displays of measurements (e.g., evidence).
- "Information" is built from the organization of data sets through quantitative and/or qualitative analysis that relate data sets, and can range from math equations, paragraphs, graphical illustrations, or images.
- "Knowledge" is created by applying experience to available measurements, data, and information.
- "Wisdom" results from the application of cognitive capability and judgment.

Complexity and the DIKW model

Even within these levels of abstraction in the discrete WKIDM model, real world complexity has introduced several subtle and often confusing distinctions. Complexity theory addresses the relationships between entities and with the context. It is often difficult to detach discrete WKIDM entities from each other and their context. The detachment makes the entities static and prone to misunderstanding, inappropriate application, and intelligence staleness. It is this inability through reductionism to separate the entities for description that has introduced several problems with discrete WKIDM based models.

Measurements are often categorized as either direct or indirect. The indirect measurement relies upon insight into the relationship of the phenomena of interest and the phenomena that can be readily measured. This can result in an inability to detach the measurement from the context and phenomena relationships. A typical example is that blood sugar can be measured directly providing descriptive performance measurement. On the other hand, thyroid function is measured through using a precursor hormone through an inferred performance measure. The latter translation to the doctor (i.e., intelligence consumer) leads to significant missed thyroid function problems.

When discussing data, they can have two forms: structured, such as bank records and data fields; or unstructured, such as documents, plots, and presentations (see Figure 2). Structured data are separated from its relationships through use of strictly defined data fields. It is often problematic that in the real world a user's name is longer that the allowed length, hence my constant battle with "vandergr" or even worse when additional data fields are needed significant cost is incurred to add them. In the unstructured data world, names have no such constraints and all data and their relationships are captured. As seen in the plot below, most of the material that is relevant to organizations is unstructured, while current information management structures are designed to work efficiently with structured data (Ribiere, 2001; CEB, 2000). Even with the push to move toward more structured data and information, the ratio has not changed much since measured in 2000. It is still estimated that knowledge work today uses 80 percent unstructured data (Identitech, 2004). Potential unstructured data value found in data mining arises from relationships thus when data are structured through detachment value is lost.

Information is usually categorized as quantitative or qualitative. For a classical SE decomposable closed system[5] quantitative information is desired. The analysis limits the number of relationships considered and usually considers only technical parameters that are easier to work with. Unfortunately, the real world tends to desire open systems[6] qualitative information. The effect of relationships on the information can be quite dramatic, such is observed with the predicted desirability of Betamax to VHS based on performance versus the observed market preference.

Within the field of knowledge management there exist two quite distinct and widely accepted types of knowledge: explicit and tacit. The generation of knowledge is done by intellectual capital applying experience. However, if the knowledge can stand alone without the context that was used in its development, it is classified as explicit knowledge. This "codified" knowledge consists of facts, concepts, lessons learned and static entity models easily captured in books and training (Wiig, 1993). It is explicit knowledge that most current knowledge management practices try to, and indeed are able to, capture, acquire, create, leverage, retain, codify, store, transfer and share.

However, if the knowledge cannot be expressed independent from its development context, it is called "tacit". As identified by Polanyi (1962, 1967), tacit knowledge is knowledge that is hard to encode and communicate. It is ephemeral and transitory and "cannot be resolved into information or itemized in the manner characteristic of

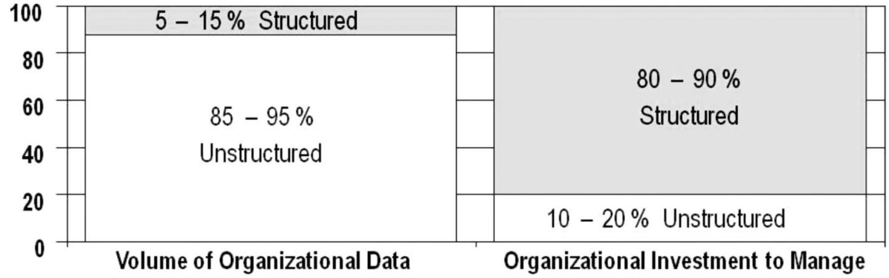

Figure 2. Organizational structured and unstructured data

information" (Oakeshott, 1991). Further, tacit knowledge is personal, context-specific and hard to formalize (Nonaka and Takeuchi, 1995; Wiig, 1993). This means to appropriately capture and transfer tacit knowledge it is important to provide the related context. This is why tacit knowledge is best shared through stories, scenarios, mentoring experiences, and social networks. It resists "widetizing", but because of its rich nature has more value and applications usually than explicit knowledge. Tacit knowledge also tends to be path dependent and thus harder to replicate.

As the story goes, there once was a factory with a very large machine with pipes intertwined throughout the length of the facility. Production relied on this machine, it worked like clockwork for many a year. Then one day it stopped. After many useless attempts to fix it, the machine still did nothing. The call went out for the specialist, who was the last hope to fix the machine. He walked in with only a rubber mallet in hand. The agreed-to price was $10,000 per visit. He did not stop at the controls or look around in the least. He walked over to a single pipe and hit it sharply once at a bend in the pipe. The machine immediately began again its production. As the expert went to collect his fee, the accountant asked, "Are you really going to charge us $10,000 for hitting the machine with a hammer?" The expert said, "No, the $10,000 is for knowing *where* to hit it!" Such is the folklore about the value of the single individual possessing the right tacit knowledge.

Wisdom has often been regarded in the research literature as the application of judgment to knowledge. It is then usually relegated to a human only endeavor. But when applying the distinction between wisdom that is detachable from the context a role for the automatable and non-automatable wisdom appears. The work in artificial intelligence has led to several developments such as expert systems that for a reducible set of cases can apply judgment.

Emergent behavior overview

The discrete WKDIM pyramid fails to meet decision-maker's needs in today's volatile world. These needs include accurate, complete, consistent, and timely Intelligence to inform decision-making and implementation. Because of the dynamic co-evolving nature of the venture and context, to be relevant intelligence must be an emergent product/capability arising from the interaction of the context and the complex venture's rules, functions, and diverse agents. To understand this assertion, it is necessary to first explore emergence concepts being developed by the complexity community.

Industrial Age complicated and Intelligence Age complex models of reality have inherently different characteristics and descriptions. Lissack and Roos (2000) have described the differences between a model of the world that has discrete, yet complicated, structure and one that has interdependent complex structure. The insight, they explain, lies in the roots of the two words. "Complicated" uses the Latin ending "*plic*" that means, "to fold" while "complex" uses the "*plex*" that means, "to weave." Thus, a complicated structure is one that is folded with hidden facets stuffed into a smaller space and can be detached from its static context. On the other hand, a complex structure uses interwoven components and dynamic context that introduce mutual dependencies and produce emergent behaviors.

Psychologist G.H. Lewes (1875) coined the term "emergent". He summarized the difference between complicated and complex systems as:

> Every resultant is either a sum or a difference of the co-operant forces; their sum, when their directions are the same – their difference, when their directions are contrary. Further, every resultant is clearly traceable in its components, because these are homogeneous and commensurable. It is otherwise with emergents, when, instead of adding measurable motion to measurable motion, or things of one kind to other individuals of their kind, there is a co-operation of things of unlike kinds. The emergent is unlike its components insofar as these are incommensurable, and it cannot be reduced to their sum or their difference.

As Aristotle (350 BC (from Ross, 1924)) observed, "a whole is other than a sum of its parts." Emergence is a valuable consequence of the interdependencies of the threads and context. For complex ventures it represents new capabilities, opportunities and potential issues. One of the attractive characteristics of emergent behavior is its ability to change dynamically as the context and the venture changes. The emergent behavior, properties, or capabilities can be repeated, but are not usually predicted before evolution or initial combination occurs.

An emergent behavior example is the wild geese "V" flying formation. It arises from the interaction of simple rules used by each individual goose in a flock and the characteristics of the atmosphere. If one tries to describe this behavior using Industrial Age processes, it requires the explanation to be as complicated as the observed phenomena. The control of the behavior also requires the governing geese to know and process a vast amount of data about the environment, aerodynamic theories, etc. In other words, it is difficult if not impossible to generate this desirable behavior using the classical SE approach. However, the geese by following these simple self-interest rules produce an advantageous emergent behavior. The behavior is emergent because it is not explicitly described by one of the geese alone or a sum of the individual actions. It allows the flock to fly faster, farther, and with less expended energy than if all the geese flew the route alone (Santosus, 1998).

Another example is complicated ant hive behavior. The ants perform seven main functions (e.g. moving pupae, cleaning trash, gathering food, and building ant hill). With a simple rule set (e.g. do not wait to do an activity) and individual agent diversity (e.g. ant strength), the division of labor is easily explained and the colony survival ensured (Gordon, 1999, 1996).

Emergent behaviors can be the result of a dynamic process evolution[7] over time, collective behavior[8] due to the interconnectedness of components and context, or combination rules and functions[9] in dynamic co-evolution. Intelligence can result from any of the emergent processes. If complexity is limited or removed from the solution space through over-constraining or too tightly controlling the solution, then much of the value of emergent behavior is lost. This would result in an internet that is static, a "stovepiped" decision support system, or slowly evolving, solutions that do not meet customer expectations.

The darker side of complex venture and the context interconnectedness is the reality of co-evolution with feedback loops (e.g., damping and amplifying) and hysteresis[10] concerns. A typical result of this feature is the higher probability of cascading catastrophic failure unless appropriate venture/context sensing and response mechanisms are provided. Thus, complex ventures are often found with extensive situational awareness and empowered agents to ensure decision making and implementation are done in a timely informed manner. In specific, as an emergent product, Intelligence is particularly susceptible to a lack of WKIDM sources and agent diversity (i.e., group think), starting point and path constraints (i.e., initial assumptions), and correct consumer identification (i.e., answering the wrong problem).

Intelligence as an emergent behavior

Extrapolating from the CIA's (1993) *Consumers Guide to Intelligence*, intelligence is the understanding of the past, the awareness of the present, and the prediction of the future for a complex venture and its context in the consumers'[11] frame of reference. Intelligence is a prelude to all decision making and action.

As shown in Figure 3, intelligence is the translation of wisdom, knowledge, information, data, or measurement (IWKIDM) into the consumers of intelligence frames of reference. The consumers of intelligence range from policy through operational levels. Given the same "ground truth" the intelligence products must be tailored to support their needs.

This tailoring has been problematic for many BI applications because of limited dashboard versatility. In addition, the need for context rich feedback from the intelligence consumer has posed significant challenges to BI developers.

Generating intelligence products goes beyond the backward looking view of "connecting the dots" where the important dots can only be truly identified after the fact. The "Intelligence" represented in the intellectual capital pyramid involves the acquisition, analysis, synthesis, and delivery of WKIDM (Waltz, 2003) translated, by either knowledge workers or automated systems, into a form usable to the intelligence consumer.

Today there is a plethora of sweet voices calling out to the unwary web surfer to come listen to their songs of information and e-mails of knowledge. The University of California Berkeley's School of Information estimated that in 2002 the world's

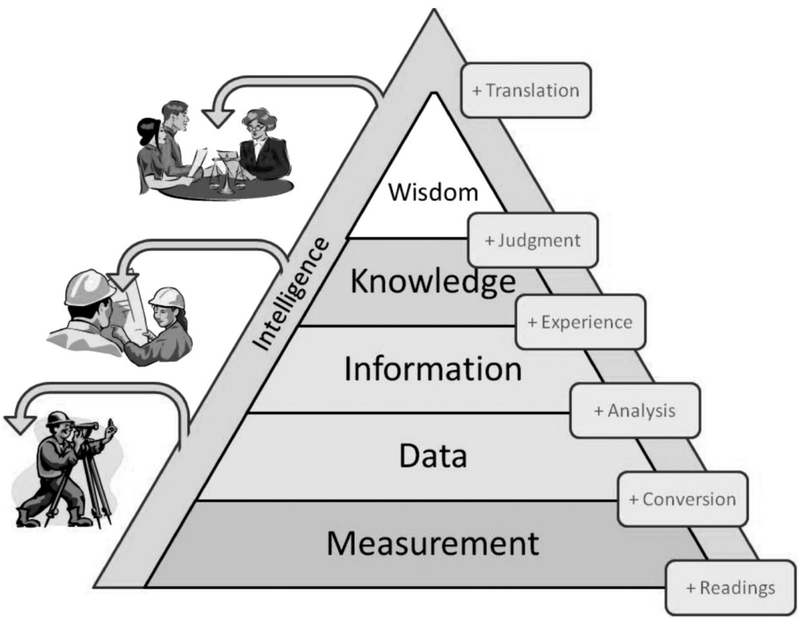

Figure 3.
IWKIDM pyramid

production of data and information amounts to 250 megabytes for every person on earth and it is growing exponentially (Lyman and Varian, 2003) It is important for the user to understand that too much WKIDM disguises the goal, confuses the vision, and produces overload. Even though the Internet and corporate intranets offer consumers an ever-expanding universe, it comes at a price, "information overload" and processing shut-down. Yet amid all this noise, complaints abound that during key decision-making and implementing processes, no useful IWKIDM is available. Many in the KM field are working to focus on getting the relevant reliable intelligence to the right people and at the right time. (Pettrash, 1996) By providing the smart balance a good KM system becomes invaluable by providing the right level of timely and reliable for the consumer. (DAU, 2003; Marchand *et al.*, 2001; Kauffman, 1995).

For some, the goal of KM is to capture the essential data, information, and experience an employee needs and filter out the rest. (Bair, 1997) This is a response to the data glut seen throughout the business environment; unfortunately, is based on the paradigm that somehow one can predict what will be necessary. This is difficult since Complexity Theory demonstrates that prediction for the long-term is impossible and little things (i.e., maybe seemingly unimportant things such as pilot training anomalies) can cause large changes. Thus, intelligence and its generation become more in a complex venture (Malhorta, 2000).

Figure 4 helps to explain the role of IWKIDM with a real-world example, consider an infrared surveillance satellite. It has a focal plane that looks down collecting photons coming from the earth below. These photons are measured as a charge build-up. The measurement, thus, is electrons or voltage. These measurements are converted to an irradiance map across the image. Thus, the data are the irradiance map across the image. A system, or human, can analyze this irradiance map to discern bright and dark areas and discern features, such as buildings, roads, and lakes. These

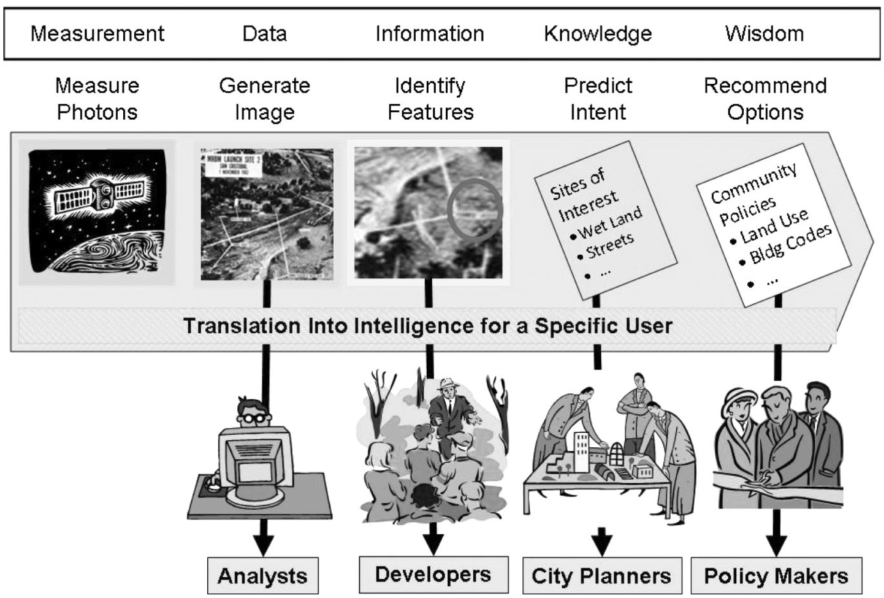

Figure 4.
Discrete WKIDM pyramid example

features are information. An image analyst with experience can distinguish which buildings are hospitals and which are factories, where are roads, and identify environmentally sensitive areas. Thus, the analyst by applying experience, converted information into knowledge about what type of buildings, roads, and terrains are contained in the area of interest. Applying human judgment (i.e., rationale) to this knowledge produces the wisdom that particular areas are prone to traffic congestion and other areas should not be open to development.

Beginning with measuring simple photons, the analysts have developed wisdom about the area under surveillance. The experts all understand the experience, tacit knowledge, and assumptions that have built to this point. Now the analyst must translate and communicate to the non-analyst consumer. This translation creates intelligence, and it requires maintaining and communicating the essence of the produced WKIDM without overwhelming the consumer. The problem often appears in this attempt to translate wisdom into intelligence; at its very core, there is a possibility for differences of interpretation. Translation must be appropriate to the consumer's level of understanding and decision support needs.

Conclusions

Complex ventures must develop a new appreciation of the value of intellectual capital, the rise of providing services as a commodity, the constantly changing business environment, and the ever-quickening operational tempo. Evolution of businesses from the past efficient enterprises to the future effective complex ventures requires new business models that go beyond marketing "glibido". Models such as the IWKIDM pyramid transform organizational thinking and demand more than re-tooling of the old assembly-line mentality. To realize their potential requires the introduction of new understandings of the non-linear complex organizational social structures and business environments. In other words, the new business model must address the impacts on an organization where complex behaviors such as intelligence arise from simple rules and small decisions can have large consequences over time. These impacts drive the increased need for worker empowerment, adaptation to the ever-changing context, leadership with decentralized decision making, integrated OODA loops, and ubiquitous IWKIDM.

The proposed intelligence pyramid with its associated definitions and insight into detached and complex entities represents the different components of a complex venture's intellectual capital represents such a new model. The venture will collect and manage all these various WKIDM entities, but the real benefit to the user/operator is the translated emergent intelligence. While engineers and developers can argue about feature design, taxonomies, and characteristics, the real benefit of the total structure is in providing the right intelligence, in the right amount, to the right place, and at the right time.

To ensure venture success, researchers have proposed that the quality of the IWKIDM entities can be summarized by four properties:

(1) accuracy (i.e. reflects real world);

(2) ompleteness (i.e. all relevant pieces present);

(3) consistency (i.e. same format for given problem); and

(4) timeliness (i.e. meets consumer's needs in an observe, orient, decide, and act (OODA) loop) (Ballou and Pazer, 1985; Tayi and Ballou, 1998; Boyd, 1987).

Thus, it is necessary to build upon a complex venture model that guides the engineering solutions that leverage emergent behavior insights to develop an improved Intelligence model for the interaction of complex venture intellectual capital (i.e. self-organizing agents) with the WKIDM pyramid entities and the intelligence products consumer context. Welcome to the Intelligence Age.

Notes

1. First coined by Tyson (1997) is a more accurate representation of the current era than the term "Information Age" hyped by the AT&T Marketing department to sell information-related technologies (Kushnick, 1998).
2. Models are the "basic structural form of experience, through which human beings engage, organize, and understand their world" (Morgan *et al.*, 1983).
3. Context is used in this paper to mean the holistic dynamic environment in which a venture operates. Historically, SE focused primarily on hierarchical relationships and tended to isolate the systems from the context in which it is contained (often by assuming the environment is "fixed" or "static" set of constraints on the system.
4. A complex venture is an undertaking that uses coherent principles and integrated resources to provide dynamic solutions with the desired behavior and value for one specific project or in a continuing enterprise in its co-evolving context, internal capabilities, and stakeholder interest
5. From Systems Theory a closed system is self-contained and not influenced by its external environment.
6. Open systems allow matter, energy, or information to flow into and/or out of the system making its behaviors subject to its surrounding environment and other systems. It is influenced by events outside of the actual or conceptual boundaries of the system. The discussion of the implications for the second law of thermodynamics is outside the scope of this paper, but is of great interest especially based on Wolfram's (2002) experimental results in this area.
7. Dynamic process emergence is an evolution of species or systems over successive generations. This type of emergence can be seen in what the internet, with its many new applications, is becoming. Innovation and empowered agents find the best fit to the unknowable users, needs, and uses.
8. Collective behavior emergence can occur over disparate size scale, such as the neuron interactions in a human brain that give rise to thought (even though the constituent neurons are not individually capable of thought). The collective behavior emergence can also result from disparate components used together to provide benefit that neither could address alone (e.g. lasers and fiber optics enhancing communications).
9. Combination emergence can result from repurposing of ideas or systems in a new context or use based on rules and standards established for the system.
10. History and prior states may have an influence on future states.
11. Intelligence consumer is defined as the decision-makers or implementers that are supported by the communication of intelligence products. In a complex venture, intelligence consumers also are IWKDIM providers.