Recombinant Knowledge Relativity Threads for Contextual Knowledge Storage

Dr. James A. Crowder
Raytheon Intelligence and Information Systems
16800 E. Centretech Parkway, Aurora, Colorado 80011

Dr. John Carbone
Raytheon Intelligence and Information Systems
1200 S. Jupiter Rd., Garland, Texax 75042

Abstract - *Research shows that generating new knowledge is accomplished via natural human means: mental insights, scientific inquiry process, sensing, actions, and experiences, while context is information, which characterizes the knowledge and gives it meaning [8]. This knowledge is acquired via scientific research requiring the focused development of an established set of criteria, approaches, designs, and analysis, as inputs into potential solutions. This cross-domain research is more commonplace, made possible by vast arrays of available web based search engines, devices, information content, and tools. Consequently, greater amounts of inadvertent cross-domain information content are exposed to wider audiences. Researchers and others, expecting specific results to queries end up acquiring somewhat ambiguous results and responses broader in scope. Therefore, resulting in a lengthy iterative learning process and query refinement, until sought after knowledge is discovered. This recursive refinement of knowledge and context occurs as user cognitive system interaction, over a period in time, where the granularity of information content results are analyzed, followed by the formation of relationships and related dependencies [17]. Ultimately the knowledge attained from assimilating the information content reaches a threshold of decreased ambiguity and level of understanding, which acts as a catalyst for decision-making, subsequently followed by actionable activity or the realization that a given objective or inference has been attained [4, 5].*

1 Introduction

Renowned fuzzy logic theorist Zadeh [24], described tacit knowledge as world knowledge that humans retain from experiences and education, and concluded that current search engines with their remarkable capabilities do not have the capability of deduction, that is the capability to synthesize answers from bodies of information which reside in various parts of a knowledge base. More specifically Zadeh, describes fuzzy logic as a formalization of human capabilities: the capability to converse, reason and make rational decisions in an environment of imprecision, uncertainty, and incompleteness of information.

Underlying decision-making based on informational inferences is a great concern, for informational ambiguity and the ramifications of erroneous inferences can be catastrophic. Often there can be serious consequences when actions are taken based upon incorrect recommendations and those can influence decision-making before the inaccurate inferences can be detected and/or even corrected. This is particularly a problem in intelligence processing. Underlying the data fusion domain is the challenge of creating actionable knowledge from information content harnessed from an environment of vast, exponentially growing structured and unstructured sources of rich complex interrelated cross-domain data.

This paper addresses the challenge of minimizing ambiguity and fuzziness of understanding in large volumes of complex interrelated information content via integration of two cognition based frameworks. The objective is improving actionable decisions using a Recombinant Knowledge Assimilation (RNA) [7] framework integrated with an Artificial Cognitive Neural Framework (ACNF) [3] to recombine and assimilate knowledge based upon human cognitive processes which are formulated and embedded in a neural network of genetic algorithms and stochastic decision making towards minimizing ambiguity and maximizing clarity.

The RNA derivation provides a mathematical relationship for context between two knowledge objects [21]. Described is the research and development to enhance the contextual development between knowledge objects, referred to as the Recombinant kNowledge Assimilation (RNA), along with the Artificial Cognitive Neural Framework (ACNF) which provides the mechanisms by which we apply additional refinement concepts and formalism for the modular Decomposition/ Reduction/Association sub-processes provided by the RNA.

2 The Problem of Contextual Knowledge

Newell and Simon [12, 13] developed models of human mental processes and produced General Problem Solver (GPS) to perform "means-end analysis" to solve problems by successively reducing the difference between a present condition and the end goal. GPS organized knowledge into symbolic objects and related contextual information which were systematically stored and compared. Almost a decade later Sternberg [23] described a now well-known paradigm called the Sternberg Paradigm where, observations of participants were taken during experiments to determine how quickly the participants could compare and respond with answers based upon the size and level of understanding of their knowledge organized into numerical sets [18, 19, 20]. Sternberg Paradigm is known for (1) organizing knowledge and modifying context while using a common process for describing the nature of human information processing and (2) human adaptation based upon changes in context. Here we introduce an artificial AI framework to provide an autonomous system for analysis of informational context.
Figure 1 illustrates the Artificial Cognitive Neural Framework (ACNF). The three main subsystems within the architecture are the Mediator, the Memory System, and the Cognitive System [2].

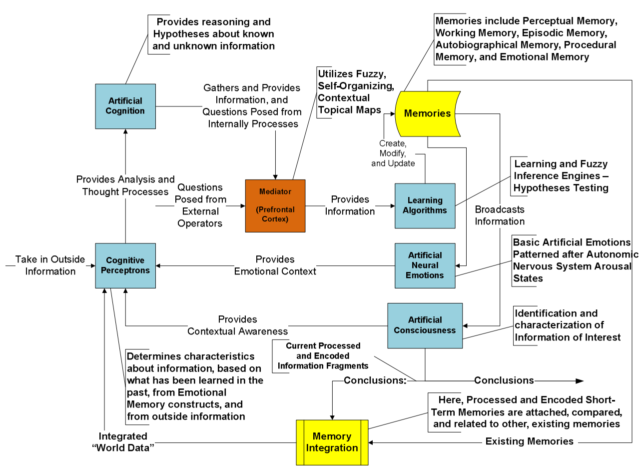

Figure 1 – The Artificial Cognitive Neural Framework

The Mediator gathers information and facilitates communication between agents. Hence, each cognitive decision is handled by the Mediator (the Artificial Prefrontal Cortex) which takes information from perceptrons and from coalitions of perceptrons and updates the short-term, long-term and episodic memories or pedigree [9]. The information available in memory (what the system has learned) is continually broadcast to the conscious perceptrons that form the cognitive center of the system (i.e., they are responsible for the cognitive functionality of perception, consciousness, emotions, processing, etc.) [10]. The purpose of the ACNF is to:

- Provide an architectural framework for "conscious" software agents.
- To provide a "plug-in" domain for the domain-independent portions of the "consciousness" mechanism.
- To provide an easily customizable framework for the domain-specific portions of the "consciousness" mechanism.
- To provide the cognitive mechanisms for behaviors and emotions for "conscious" software agents.

The use of an ACNF for analysis, reasoning, and reporting provides the "Cognitive Intelligence" to allow the top-down executive processing required for real-time cognitive reasoning.

Outlining the need for frameworks which can analyze and process knowledge and context, Liao [25] represented context in a knowledge management framework comprising processes, collection, preprocessing, integration, modeling and representation, enabling the transition from data, information and knowledge to new knowledge [11]. The authors also indicated that newly generated knowledge was stored in a context knowledge base and used by a rule-based context knowledge-matching engine to support decision-making activities. Gupta and Govindarajan [26] defined a theoretical knowledge framework and measured the collected increase of knowledge flow out of multinational corporations based upon "knowledge stock" (e.g., the value placed upon the source of knowledge). Pinto [27] developed a conceptual and methodological framework to represent the quality of knowledge found in abstracts. Suh [28] concluded that collaborative frameworks do not provide the contents which go in them, therefore, content was discipline specific, required subject matter experts, and clear decision making criteria. Additionally, Suh noted that processes promoting positive collaboration and negotiation were required to achieve the best knowledge available, and were characterized by process variables and part of what is defined as the Process Domain. Finally, Ejigu et al. [29] created a framework for knowledge and context which collected and stored knowledge as well as decisions in a knowledge repository that corresponded to a specific context instance. Subsequently, the framework evaluated the knowledge and context via a reasoning engine.

Today, existing databases housing vast bits of information do not store the information content of the reasoning context used to determine their storage [29]. The knowledge collection and storage formula was therefore developed to include and store relationship context along with knowledge, recursively. This means that, each act of knowledge and context pairing shown as in equation shown in Figure 1 $\sum_{i,j} K_i(R_j)$, recursively examined all of the previous relationships as they were recombined into storage since they were all related and dependent on each other. Recursive refinement then occurred, per iteration of relationship pairing. Recursive refinement occurred when the user found what was looked for shown as $K_i(R_j)$, using interrogatives, (e.g. who, what when, where, why and how) [30, 31]. The information content contributing to finding the answer then has significant value and therefore, a higher degree of permanence in the mind of the stakeholder [32]. Therefore, the information content has reached a threshold where retaining the knowledge and context has become important.

3 Knowledge Relativity Threads

Figure 2 represents a Knowledge Relativity Thread (KRT). This approach for presentation of knowledge and context and was constructed to present five discrete attributes, namely, time, state, relationship distance, relationship value, and event sequence. The goal of a KRT is to map the dependencies of knowledge and related attributes as knowledge is developed from information content. In this figure, the timeline represented by the blue arrow from left to right, shows the events or state transitions in sequence and captures the decision points. During each of the iterations of the presentation of knowledge and context, intrinsic values were captured and placed close to each colored knowledge component. In Figure 2, these are represented as information fragments under the cycles. The Basic Information Decomposition depicts how a KRT looks when it represents information decomposed into pieces; in this case fragments. The red triangles, added next, depict a particular state for each of the iterations, in the KRT development cycle. For emphasis, each colored sphere was built into the depiction and added in sequence to represent the fact that each information fragment follows the other. Each icon represents each information fragment. The relative values in this Basic Knowledge Decomposition between each sphere are perceived to be of the same value to each other. Therefore, the lines are the same distance as well. Since, this base representation depicted in Figure 2 can present time, state, and sequence, as well as, relationships, the challenge was addressed as described by Dourish [33] to create presentation of context which can visually capture and manage a continually renegotiation and redefinition of context as development of knowledge occurs over time.

The KRT depicts cognitive comparison of not just information, but of the contextual relationships also. An important distinction about the observation of each comparison is that each is made from the perspective of the aggregated of information, knowledge, and context.

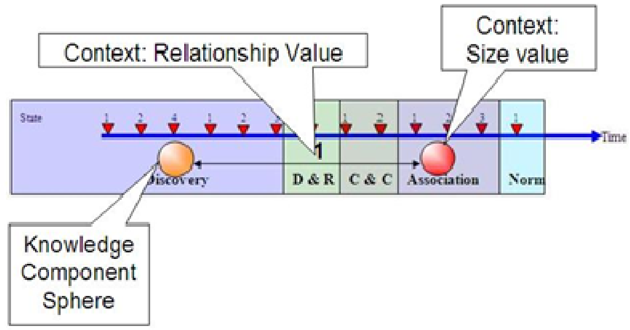

Figure 2– The Knowledge Relativity Thread

The representation of knowledge and context formula is introduced here and is presented by Equation (1). The independent results which follow are mathematical evaluations extended from Newton's law of gravitation shown in Equation (3-1). Newton's Law of Gravitation formula is:

$$F = G\frac{(M_1 M_2)}{r^2} \quad (1)$$

where:

- F is the magnitude of the gravitational force between the two objects with mass,
- G is the universal gravitational constant,
- M_1 is the mass of the first mass,
- M_2 is the mass of the second mass, and
- r is the distance between the two masses.

This equation was used as an analogy for the derivation of mathematical relationship between a basis, made up of two objects of knowledge [7].

Abstracting Newton's Law of Gravitation as an analogy of Equation (1), representing relationships between two information fragments, using context, is written as Equation (2) shown below, which describes the components of the formula for representing relationships between information fragments using context:

$$A = B\frac{(I_1 I_2)}{c^2} \quad (2)$$

Where:

- A is the magnitude of the attractive force between the information fragments,
- B is a balance variable,
- I_1 is the importance measure of the first information fragment,
- I_2 is the importance measure of the second information fragment, and
- c is the closeness between the two information fragments.

Comparing the parameters of Equation (1) and Equation (2) F and A have similar connotations except F represents a force between two physical objects of mass M_1 and M_2 and A represents a stakeholder magnitude of attractive force based upon stakeholder determined importance measure factors called I_1, and I_2. As an analogy to F in Equation 1, A's strength or weakness of attraction force was also determined by the magnitude of the value. Hence, the greater the magnitude value, the greater the force of attraction and vice versa. The weighted factors represented the importance of the information fragments to the relationships being formed. The Universal Gravitational Constant G is used to balance gravitational equations based upon the physical units of measurement (e.g. SI units, Planck units). B represents an analogy to G's concept of a balance variable and is referred to as a constant of proportionality. For simplicity, no units of measure were used within Equation (2) and the values for all variables only showed magnitude and don't represent physical properties (e.g. mass, weight) as does G. Therefore, an assumption made here is to set B to the value of 1:

For simplicity, all of these examples assume the same units and B was assumed to be one. The parameter c in Equation (2) is taken to be analogous to r in Equation (1). Stakeholder perceived context known as closeness c represented how closely two knowledge objects (information fragments) (KO) are related. Lines with arrows are used to present the closeness of the relationships between two pieces of knowledge presented as spheroids (see Figure 3).

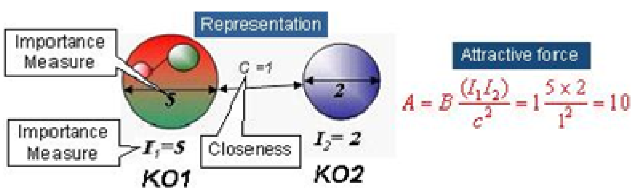

Figure 3– Representation of Knowledge Object and Context

Using Equation (2), the value of the attraction force $A_{1\rightarrow 2}$ = 5 x 2 divided by the relative closeness/perceived distance^2 = 1. Hence, the attraction force A in either direction was 10. The value of 10 is context which can be interpreted in relation to the scale. The largest possible value for attraction force A with the assumed important measure 1-10 scale is 100, therefore a force of attraction value of 10 was relatively small compared to the maximum. This means that the next stakeholder/ researcher understood that a previous stakeholder's conveyance was of small relative overall importance. However, the closeness value of 1 showed that the two objects were very closely related. Figure 4 therefore shows that when using Equation (2), if relationship closeness and/or perceived importance measure of the knowledge objects change value, as new knowledge or context is added and evaluated, then it follows that relationship force of attraction will change.

4 Frameworks for Contextual Knowledge Refinement

As the knowledge and context foundation described above depicts the process and tools for enhancing knowledge and context the Artificial Cognitive Neural Framework expounded upon in the following sections describe the mechanisms by which we apply additional refinement concepts and another formalization for the modular Decomposition and Reduction and Association sub-processes described in the RNA above.

Here we refer again to the ACNF illustrated in Figure 1. The Mediator gathers information and facilitates communication between agents. Hence, each decision handshake of a combined RNA-ACNF system is handled by the Mediator which takes information from perceptrons and from coalitions of perceptrons and updates the short-term, long-term and episodic memories or pedigree. The information available in memory (what the system has learned) is continually broadcast to the conscious perceptrons that form the cognitive center of the system (i.e., they are responsible for the cognitive functionality of perception, consciousness, emotions, processing [14, 15], etc.)

The ACNF contains several different artificial memory systems (including emotional memories) [1, 3], each with specific purposes. Each of these memory systems are stored pedigree used in the recursive RNA process and are integrated during the processes of relationship formation between objects of knowledge and context [6].

When processing pedigree memory, RNA loosely categorizes the granularity of information content into knowledge and context based upon the criteria established by the cognitive human interaction input into the system. These loosely or fuzzy categories are only as fuzzy as the threshold of human understanding. Therefore, in order to artificially create this effect we use Intelligent Software Agents to develop fuzzy organization over time, ultimately reaching a threshold of perceived understanding relative to the initially specified set of criteria.

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Illustrated in Figure 4 is an FSSOM with information search hits superimposed. The larger hexagons denote information sources that best fit the search criterion. The isograms denote "closeness"; how close the hits are to particular information topics or criterion.

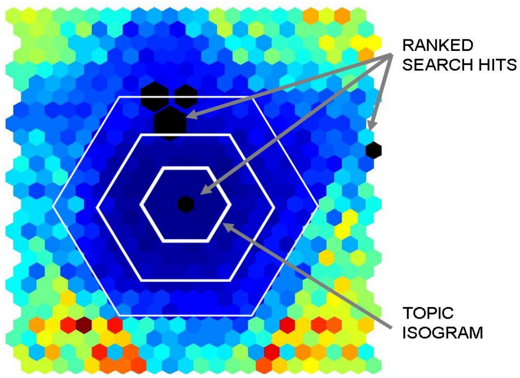

Figure 4– The Fuzzy, Semantic, Self-Organizing Topical Map

There are also other attributes to be explored that would provide significant benefit: as a natural language front end to relational data [6].

Once the FSSOM has been developed, it can be enhanced to include a higher-level Topic Map. This high-level Topic Map describes knowledge structures that span multiple documents. The key features of the Topic Map, illustrated in Figure 5, are the topics, their associations and occurrences in the FSSOM. The topics are the areas on the FSSOM that fall under a topic name. The associations describe the relationships between topics, such as 'biometric data' in 'bone fractures'. The occurrences are the links from the FSSOM into the documents used to form the FSSOM.

5 The Dialectic Search (DS)

The Dialectic Search uses the Toulmin Argument Structure to find and relate information and memories that develops a larger argument, cognitive inference [22]. The Dialectic Search Argument (DSA), illustrated in Figure 6, has four components:

- **Information and Memories**: both in support of and rebutting the argument or hypothesis under analysis by the APC.
- **Warrant and Backing**: explaining and validating the hypothesis.
- **Claim**: defining the hypothesis itself
- **Fuzzy Inference**: relating the information/memories to the hypothesis.

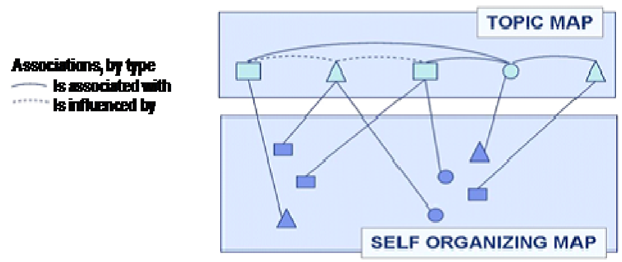

Figure 5– Superimposing High-Level Topical Maps on the FSSOM

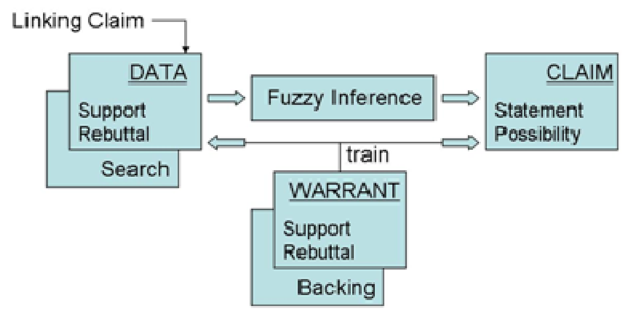

Figure 6– The Dialectic Search Structure

The Dialectic Search serves two purposes:

- First, it provides an effective basis for mimicking human reason.
- Second, it provides a means to glean relevant information from the Topic Map and transform it into actionable cognitive intelligence.

This approach is considered dialectic in that it does not depend on deductive or inductive logic, though these may be included as part of the warrant. Instead, the Dialectic Search depends on non-analytic inferences to find new possibilities based upon warrant examples. The Dialectic Search is dialectic because its reasoning is based upon what is plausible; the Dialectic Search is a hypothesis fabricated from bits of information.

As the Dialectic Search lattice develops, the aggregate possibility is computed using the fuzzy membership values of the support and rebuttal information. Eventually, a Dialectic Search lattice is formed that relates information with its computed possibility. The computation, based on Renyi's entropy theory, uses joint information memberships to generate a robust measure of Possibility, a process that is not possible using Bayesian methods [3].

There is one other valuable attribute to using the

FSSOM method. Because the vector that represents the information is a randomly constructed vector, it cannot be decoded to reformulate the source; the source must be reread. This is critical to protecting compartmentalized information. Using the FSSOM, the protected source can be included in the FSSOM and used to support/rebut an argument without revealing the detailed information.

6 Conclusions and Discussion

As we push to process, analyze and correlate more and more information, the need to combine contextual relevance with information is ever more necessary. When describing how science integrates with information theory, Brillouin [35] defined knowledge succinctly as resulting from a certain amount of thinking and distinct from information which had no value, was the "result of choice," and was the raw material consisting of a mere collection of data. Additionally, Brillouin concluded that a hundred random sentences from a newspaper, or a line of Shakespeare, or even a theorem of Einstein have exactly the same information value. Therefore, information content has "no value" until it has been thought about and thus turned into knowledge.

Information without context is just that, devoid of real content. Instead, the systematic approach presented here, combining the RNA contextual approach, with a cognitive framework, in the ACNF, provides the framework that can handle cognitive processing of information and context, turning them into actionable intelligence. The use of Knowledge Relativity Threads represents the next generation of information analysis and will greatly enhance the capabilities of information processing systems to make sense of increasing volumes multivariate, heterogeneous information [16].

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