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Ontological Issues in Higher Levels of Information Fusion: User Refinement of the Fusion Process

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Abstract – *Real-world data fusion systems process at the lowest level and combine data to a usable form for the human at the highest level. The functional role of the data fusion system is to provide timely and accurate data to the user. The focus of this paper is to address the user needs for a fusion system based on the ontological principles of "becoming" versus the historical opposite of "being". Ontology is a question of the existence of the world, but also equally important in a philosophical argument is that of an epistemology – or a set of rules. We explore the higher-level purpose of fusion systems by setting up the world and emphasizing rules to guide a fusion system design that would allow for human refinement such as active reasoning, situation awareness, and pedigree consistency.*

Keywords: Fusion, Ontology, Epistemology, Pedigree, Situational Awareness

1 Introduction

The Greeks focused on both data fusion and the philosophical questions of an **ontology** - *the study if the nature of existence.*[1] For data fusion, the focus was on the integration of senses (i.e. Aristotle) [2]. The ontological questions focused on the existence of man and whether or not man could learn about the world through sensing. Thus, the combination of ontology and fusion were united in the aspects of how the human interacted with his environment.

One of the major issues to describe the existence of humans was that of "being" or "becoming". Something that is unchanging and thus, in principle, is capable of being known with certainty is **Being**. Being implied that we exist with *certainty*, and that man exists outside the world. Being is also a philosophical realization that man can think through complex issues without sensing the world. The issues surrounding **Becoming**, implied the seeking of knowledge and truth through exploration of the world. According to Heraclitus, the state of everything in the universe is *dynamic* - that is, becoming something other than what it was.[2] One of main groups springing from this group was the experimentalists who developed methods of statistics which is fundamental to fusion processing. The experimentalists collected data and processed it to understand the world around them. Being implies stability and certainty; becoming implies instability and uncertainty in a dynamically changing world. It is not difficult to see that the fusion community subscribes to a "becoming" philosophical ontology.

The ontological questions surrounding fusion is not a new question, but it is a fundamental question when put in the framework of the "purpose" and "functional role" of fusion systems. In the modern day exploration of the fusion question, the thing that is separates the Greek philosophical questions and modern day fusionists is the computer. The computer can process large amounts of data and fusion systems seek a reduction is dimensionality to make available to users, information that can be acted on. In essence, fusionists must address an ontological question of an "extended" sensing fusion ontology including issues associated with a human interaction, information pedigree, and situational awareness.

Some of the fusion questions for an ontology have been explored in the literature and an example is from the Fusion02 conference there are common fusion questions be addressed by an ontological reasoning approach. The DAML (DARPA Agent Markup Language) program is seeking to develop a symbolic ontology for situation awareness [3]. From the ontological questions of DAML, Kokar, *et al* [3] describes an ontology for recognition while Capraro *et al* [4] address a hardware and software ontology to deal with a large amount of data and taxonomy to assist the user. When dealing with a large database, the human needs the ability to query the information needed as described by D'Agostino in a robotics example [5], McDaniel [6] in a command and control architecture, Fransson, *et al* [7] in a Situation Assessment tool, and Wright, *et al* [8] in an inferencing engine. To explore the query processing by the human, Anken [9] and Masters [10] explore a schema approach for a question-answer ontology between the human and the fusion systems. The papers listed above show a general theme of the fusion community to explore the higher levels of information fusion which includes the human as a key component in the fusion system. Blasch and Plano [11] have described the interaction between the human and the fusion system as an interaction between the human and the four levels of the JDL fusion model with the highest level (Level 5) being that of User refinement. One of the best examples of user issues includes situation awareness by Endsley [12] and Roy *et al* [13, 14] which includes elements of impact assessment.

This paper suggests some ontological concerns for data fusion with a bias towards the highest level of data fusion – user refinement. The rest of the paper is as follows: Section 2 details the Greek philosophical ideals that were prevalent in the first ontological debates and outlines for the reader, the purpose for the ontological issues surrounding human-computer interactive fusion. Section 3 details the issues higher levels of information fusion. Section 4, utilizing the framework as the human as the highest level of information fusion, explores the ontological issues surrounding a fusion system including an epistemology. Section 5 summarizes the need for a focused strategy for fusion from the lowest levels of data collection to information processing.

2 Early Ontological Questions

In his search for truth, **Socrates** used a method called inductive definition. He started with an examination of instances of such concepts as beauty, love, justice, or truth which are hard to measure and quantify. Socrates then moved on to questions of what is beauty and why things are through a theory of **essence.** The essence of something is its basic nature, its identifying, enduring characteristics.[2] Using the argument of Socrates, fusionists are concerned with the underlying primitives of concepts we seek to separate for decision making.

2.1 Defining a taxonomy of knowledge

Socrates student, **Plato** postulated a **theory of forms** - the pure, abstract realities that are unchanging and timeless and therefore knowable.[15] Such forms create imperfect manifestations of themselves when they interact with material. It is these imperfect manifestations of the forms that are the objects of our sense impressions. Plato's contention is that ultimate reality consists of abstract ideas or forms that correspond to all objects in the empirical world. Knowledge of these abstractions is innate and can be attained only through introspection.

What becomes of those who attempt to gain knowledge by examining the empirical world via sensory experience? According to Plato, they are doomed to ignorance or, at best, opinion. The only true knowledge involves grasping the forms themselves, and this can be done only by rational thought. Plato summarized this viewpoint with his famous analogy of the **divided line**, which is illustrated in Figure 1. Imagining is seen as the lowest form of understanding because it is based on images - for example, a portrait of a person is once removed from the person. Intelligence and knowledge are the highest levels of information abstraction.

	Objects	States of Mind
Intelligible World	The Good Forms	Intelligence (noesis) or Knowledge (episteme)
	Mathematical Objects	Thinking (dianoia)
World of Appearances	Visible Things	Belief (pistis)
	Images	Imagining (eikasia)

Figure 1: Plato's analogy of the divided line. (From Cornford's translation of Plato's Republic. 1968, p.222.)

Both Plato and Aristotle were primarily interested in essences or truths that went beyond the mere appearance of things, but their methods for discovering those essences were distinctly different. For Plato, essences corresponded to the forms that existed independently of nature and that could only be arrived at by ignoring sensory experience and turning one's thoughts inward (that is, by introspection). For Aristotle, essences existed but could become known only by studying nature. He believed that if enough individual manifestations of a principle or phenomenon were investigated, eventually one could infer the essence that they exemplified. For Plato, first principles were arrived at by pure thought; for Aristotle, they were attained by examining nature directly.[2]

2.2 Understanding and Reasoning

Aristotle believed sensory experience to be the basis of all knowledge, although the five senses and the common sense provided only the information from which knowledge could be derived. Aristotle also believed that everything in nature had within it an entelechy (purpose) that determined its potential.[16] Active reason, which was considered the immortal part of the human soul, provided humans with their greatest potential, and therefore fully actualized humans engage in active reason. Because everything was thought to have a cause, Aristotle postulated an unmoved mover that caused everything in the world but was not itself caused.

To truly understand anything, according to Aristotle, we must know four things about it. That is, everything has the following four causes:

1. **Material cause** is the kind of matter of which an object is made. For example, a statue is made of marble.
2. **Formal cause** is the particular form or pattern of an object. For example, a piece of marble takes on the form of Venus.
3. **Efficient cause** is the force that transforms the matter into a certain form - for example, the energy of the sculptor.
4. **Final cause** is the purpose for which an object exists. In the case of a statue, the purpose may be to bring pleasure to those who view it. The final

cause is "that for the sake of which something exists." A final cause (a thing's purpose) actually precedes the other three causes.

Using the ontological debate of the Greeks, we see that fusionists would follow Aristotle when defining a purpose for the fusion system while understanding the various causes of information.

For Aristotle, as for most Greek philosophers, a soul was that which gives life; therefore, all living things possess a soul. According to Aristotle, there are three types of souls, and a living thing's potential (purpose) is determined by what type of a soul it possesses.

1. A **vegetative (or nutritive) soul** is possessed by plants. It allows only growth, the assimilation of food, and reproduction.
2. A **sensitive soul** is possessed by animals but not plants. In addition to the above functions, organisms that possess a sensitive soul sense and respond to the environment, experience pleasure and pain, and have a memory.
3. A **rational soul** is possessed only by humans. It provides all the functions of the other two souls but also allows thinking or rational thought.

For a fusionist, we can utilize the tripartite soul approach to human interaction with three levels of automatic, associative, and cognitive functions.

2.3 Common Sense and Active Reason

As important as sensory information was to Aristotle, it was only the first step in acquiring knowledge. In other words, sensory experience was a necessary but not a sufficient element in the attainment of knowledge. In the first place, each sensory system provides isolated information about the environment that by itself is not very useful. For example, seeing an object move provides a clue as to its condition, hearing it move provides another clue, smelling it may give a clue as to why it is running, and touching may reveal that it a decoy. It is the combined information from all the senses that allows for the most effective interactions with the environment.

Aristotle postulated a **common sense** as the mechanism that coordinated the information from all the senses.[2] The common sense, like all other mental functions, was assumed to be located in the heart. The job of common sense was to synthesize sensory experience, thereby making it more meaningful. However, sensory information, even after it was synthesized by common sense, could provide information only about particular instances of things. Passive reason involved the utilization of synthesized experience for getting along effectively in everyday life, but it did not result in an understanding of essences, or first principles. The abstraction of first principles from one's many experiences could be accomplished only by active reason, which was considered the highest form of thinking. Aristotle therefore delineated levels of knowing or understanding much like Plato's divided line:

- **Active reason**: The abstraction of principles, or essences, from synthesized experience
- **Passive reason**: Utilization of synthesized experience
- **Common sense**: Synthesized experience
- **Sensory information**: Isolated experiences

An example of how these levels of understanding are related might be to experience a car through the senses of sight (seeing an car move), vibration (riding in a car), and hearing (hearing the engine). These experiences would correspond to the level of sense reception. The common sense would indicate that all these experiences had a common source - car. Passive reason would indicate how a car could be used in a variety of practical ways, whereas active reason would seek the laws governing a car's motion and an understanding of its essence. What started as a set of empirical experiences ends as a search for the principles that can explain those experiences.

The active reason part of the soul provides humans with their highest purpose. Just as the ultimate goal of an seed is to become an tree, the ultimate goal of humans is to engage in active reason.

3 Human-Fusion Interaction

One fusion model that has been utilized by fusion community is the JDL fusion model, which has been adapted to highlight the need for human refinement [11]. In the JDL-User model, the focus is the human's ability to perform active reasoning capabilities over the other fusion stages to seek knowledge about the world.

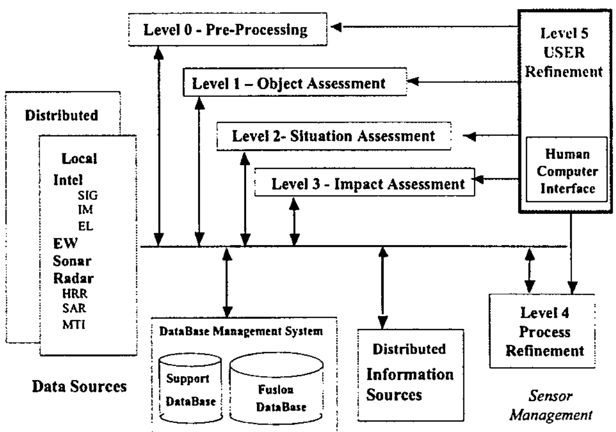

Figure 1. JDL-User Model

In the model, level 5 – User refinement is described as an element of Knowledge Management: adaptive determination of who queries information and who has access to information. (e.g. information operations) and adaptive data retrieved and displayed to support cognitive decision making and actions (e.g. altering the sensor display). While many fusion models explore the capabilities of the human, it is not a question of where the boxes go, but what is the focus of fusion system.

From the analysis of the Greek ontological question, fusionists subscribe to the theory of a changing world with dynamic objects (Level 1). A computer is good at processing large amounts of object data while a human is good at inferencing over the data. Thus, the key to the human refinement question is the "what framework the human has to inference over on the data and what capabilities allow for active reasoning?"

To develop the user requirements or refinements, three issues are paramount (1) situational awareness, (2) prioritization of needs, and (3) pedigree information.

3.1 Situational Awareness

The Human in the Loop (HIL) of a semi-automated system must be given adequate situation awareness (SA). According to a pioneer and continued leader in the SA literature, Endsley stated that "Situation awareness is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future." [12]. This now-classic model translates into 3 levels:

- Level 1 SA - Perception of environmental elements
- Level 2 SA - Comprehension of current situation
- Level 3 SA - Projection of future states

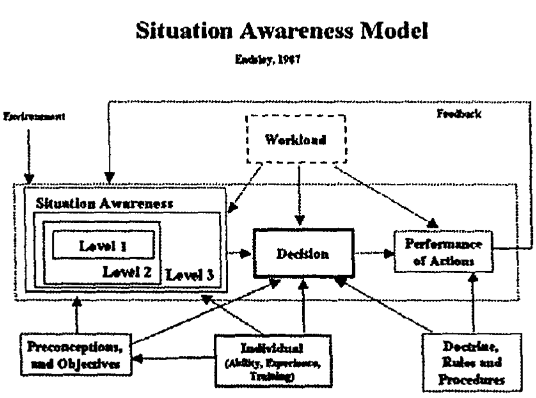

Figure 2. Endsley's Situation Awareness Model.

Operators of dynamic systems use their situation awareness in determining their actions. To optimize decision making, the SA provided by a system should be as precise as possible as to the objects in the environment (Level 1 SA). A situation awareness approach should present a fused representation of the data (Level 2 SA) and provide support for the operator's projection needs (Level 3 SA) in order to facilitate operator's goals. From the SA model presented in Figure 2, workload is a key component of the model that affects not only SA, but also the decision and the action of the user in performing active reasoning.

Issues associated with the awareness of the human are (1) workload, (2) attention and (3) trust [11]. In the case of workload, we minimize the amount of information the human must process which also helps to highlight the need for different types of "cause" information for the user. Trust will be discussed in the efficacy section; however the ontological question is the ability to convey information on the computer as extended sensory information, about the truth of the world. False data would hinder the direct connection between the user and the world around them.

3.2 Prioritization of Needs

To reduce the set of information to a dimensionally attractive set of information requires that a hierarchy of needs is determined by the human processed by the fusion system. A hierarchy of needs helps to allow the human to perform active reasoning over the data. In this case, we can postulate the needs by addressing the impact assessment (Level 3) questions. Some of the needs that can be included in a hierarchy include:

Things:
- Objects – Number and types
- Threat – whether harmful, passive, or helpful
- Location – close or far
- Basic primitives – features
- Existence known or unknown – (i.e. new objects)
- Moving or static

Processes:
- Measurement system reliability (uncertainty)
- Ability to collect more data
- Delays in the measurement process

It is the user that must interact with a fusion system to determine the priority. The priority of information is related to the information sought, but to provide the human with the ontological ability to understand the world, they must have the ability to choose or select the objects of interest and the processes from which the raw data is converted to the fused data. One of the issues in the processing of fused information is related to ability to understand the origin of the information or pedigree of the data and information.

3.3 Pedigree Information

Pedigree information is the *origin or history of something* [1]. In the case for a fusion system, it is important to understand where the data originated from, however, the availability of pedigree information is not necessary for the human unless there is a conflict of information. When a conflict arises, the human needs to be able to drill down from the fusion result to the data processed. This not only includes the information type and collection but also the time of the information. Understanding when the data was transformed into information is important for the human to make decisions on.

Pedigree information ensures that the data being processed is consistent and traceable to ensure the integrity of the information. Having an ontology of information leads to an interoperability between systems since the consistency of one system is related to the next (see the section on taxonomy, semantics, and efficacy).

Some of the issues in pedigree include:

Integrity – formal correctness (i.e. uncertainty analysis)
Consistency – reducing ambiguity or double counting (i.e. measurement origination)
Traceability - backward inference chain (i.e. inferences assessed as data is translated into information).

In the case in which pedigree information is (1) decomposed from the user to the machine and (2) composed from the machine to the user, below are listed a pedigree taxonomy [17] to accomplish a fusion task:

Decomposition Pedigrees

<u>**(A) Information Pedigree:**</u> Links information needs decomposition elements-of-information from collection task to cognitive information need

Defines System Objective Model (SOM)

<u>**(B) Context Pedigree:**</u>

Links decomposition decision context to elements-of-information in SOM (e.g. situation, predictive assumptions, target models, doctrine)

Composition Pedigrees

<u>**Source Pedigree:**</u>

Lineage of evidence used to develop fusion products.

"Drill Down" to observation source in Situation Estimate

<u>**Processing Pedigree:**</u>

Links context used to "fuse" data with uncertainty/error associated with the hypotheses/observations in the inference chain of the source pedigree.

3.4 Utility of Pedigree information

Using the taxonomy of pedigree information provided above, there are some elements of the utility of the information that should be addressed.

Context Pedigree is a decomposition product that is essential for useful exploitation of fusion systems. The context can be a form of the situation assessment. Having the essential context information is required for consistent operational assessment of dynamic and uncertain data, which was mentioned in the ontological issues associated with the existence of information. Additionally, context pedigree requires common knowledge of sensor and data models between fusion and needs decomposition and requires consistent resource performance and asset behavior models. While having the correct context information is needed, having the correct information within the context framework is also needed.

Information Pedigree, which can be derived from an Information Needs decomposition, is really the decomposition of the user needs into actionable and control data collection for fusion results. Having the correct information enables effective assessment of new information needs and focuses fusion processes on the goals of the user. The information pedigree links the data collected to the situation assessment and the data base of information from which both the user and the fusion system reason over. Once the context establishes the information, the data fusion system needs a processing pedigree.

Processing Pedigree is a function of the composition product from the data fusion system. The processing pedigree is essential for anticipatory resource management. In the case in which the user can proactively affect the fusion system, the user needs to be able to interact with the system at various levels of abstraction. To estimate a marginal fusion gain from differing sensors, geometry, etc., the user must have the ability to know at what stage the fusion process is in. Processing pedigree requires consistent models of phenomenology, platforms, and sensors as well as requires traceability of derived products to the source.

Source Pedigree, which helps in the analysis of the derived results from information composition (i.e. fusion), needs to be maintained in situation database. Source pedigree enables understanding of degree to which information satisfies commander's needs and helps the user 'Know what it doesn't know' to drive new information needs. Once the user is aware of the source limitations, they can be linked to collection database so as to determine if other data exists.

In order to process the pedigree information from either decomposition or composition, metrics need to be established to coordinate the validity of the information. Fusion processes simultaneously contribute to uncertainty metrics associated with processing and context pedigrees for information products which form a basis for uncertainty calculus to predict satisfaction. Additionally, Processing & Context Pedigrees need to be semantically consistent and source and information pedigree require a taxonomy of consistency with database and the user.

Some additional pedigree topics include: Semantic pedigree, age pedigree, and categorical/taxonomy pedigree

3.5 Human refinement

To actively reason over a complex set of data, a usable set of information must be available from which the human can act on. The ontology – *the seeking of knowledge and the determination of the world,* [2] indicates that the world must be defined and the next section explores issues related to an ontology for human refinement.

4 Ontological Issues

In seeking the knowledge of the world through measurement, we have to define context of the information we are interested about. To create an analogy, we use a **game** to define the world of information and processes of interest for which the user inferences over.

4.1 Ontology

Ontology is based on the goal of the system. Utilizing the same arguments from the Greeks implies that we should consider the purpose or existence of something. In this case, we can divide the knowledge problem into three areas (1) world or frame of reference, (2) fusion processes, and (3) types of reasoning ontology. This paper explores only one idea for an ontological framework and there are others that exist until falsified. For an ontology of knowledge, it is noted from Plato's definitions that

Beliefs are many, but Knowledge is rare and focused [20]

In designing a sensor fusion system, we are interested in what we are trying to accomplish, which can be framed as a **knowledge game**, or the types of knowledge we are trying to seek. An analogy is that if we are playing a game, (1) which ballpark are we playing? For a fusion system, the game is to determine the objects in the world – their location, movement, and status. Once we have decided which game we are playing, we have established the ontology of the fusion system. The ontology is the declaration of world and its constructs (i.e. natural world, sensing). Next we need the epistemology (*set of rules to know something*) of the game. For a game analogy, we have to know whether or not the rules we are playing by would (2) allow us to win the game? To win, we have to define the fusion rules to declare that we have won – such as determining the object identity within some probability of quality.

For example, if Plato wanted to know something to win the knowledge game he postulated three things

A) **Proposition** – has to be true, not false and not beliefs
B) **Believe** in the truth – agree with the assumptions
C) **Evidence** to support the truth (very difficult to do)

In a fusion system, we are concerned with determining whether or not we have accumulated evidence to support a proposition in something. For example, in a fusion system, we seek features to determine the object identity. If the information gathered does not combine to create a confident belief in the proposition of an object as a specific target, then we seek additional evidence from other sensory data to improve the belief in a target type. The ontology for the fusion system is based on algorithms to combine data and thus, we move from the knowledge game to the science game.

The second game that we play is the **science game** which is the mathematics and the data collection to determine the believability of the fused results. We might infer that we have an ontology of a knowledge game, but rather we are playing a specific science game, which can be referred to as the FUSION GAME.

The **fusion game** has a similar structure to the ontological questions of the past. In the case of a fusion game, the ontology is the materialism of finding objects and feature data of interest. The Epistemology – rules, methods, and processes, include the mathematical principles of the game. One advantage of the fusion game is that nature is arbiter of the game. Nature is the truth data that tells the fusionist whether or not the determination of information is correct. Thus, to win the fusion game, we desire no anomalies (i.e. scientific knowledge is reproducible/ mathematical). Thus, if the mathematics is developed in one situation, it should be portable to another situation. The mathematical principles cover the inductive reasoning over information, while a deductive empirical analysis comes from the observations of data and fused results.

Inductive reasoning is the determination of Plausible belief – expectations / predictions – from a set of observations. To accomplish the inductive reasoning, a fusion system needs to gather the hypothesis from the user and data to test the hypothesis. The information needs to be in a framework of a testable hypothesis that can be verifiable or falsifiable hypothesis. To be able to verify a hypothesis, features must be predictable (i.e. from a model) and observable - hence sensing.

Another methodology includes **deductive reasoning** which is the case of looking at the world and determining why such things exist. One example is that of the movement of systems. We understand that objects fall to the earth and deduce that something, gravity, causes the objects to fall. Many of the deductions on object motions come from the mathematics deduced from the world, such as inertia.

Once we have defined the ontology, we now can formulate the epistemology of information.

4.2 Epistemology

It is important to discuss the epistemology of a philosophical argument as defined through the ages in positing a theory. The epistemology for fusion is based on the ontology chosen which includes (1) active reasoning, and (2) display issues such as semantics, efficacy, and a taxonomy.

4.2.1 Active Reasoning

In the case presented for a user to interact with the fusion system, the user can also take a proactive role in the assessment of data collection (i.e. level 4 – sensor management). A user can act in a variety of abilities such as monitoring a situation in an active or passive role or planning by either reacting to new data or proactive control over the fusion system. Thus, the human has to decide in which way to convey information: such as **Monitor** (active versus passive) or **Planner** (reactive vs. proactive)

When a human interacts with a system, it is important the ability of reasoning be available for the fusion system. The human has the abilities to quickly reduce the search space of the fusion system and hence, guide the fusion system process. Such an example is when the human cues a fusion system to look for an object in a certain area of the earth. The human can provide many roles to interact with a fusion system, such as predicting target motions, reacting to new information, and proactively cueing the system to search for things that are assumed to exist. If human does not take an active role in monitoring a fusion system, then the person is acting in a passive role, shown in Figure 3.

Predictive – projective, analytical (anticipatory)
Reactive – immediate, unthinking
Proactive – practical / active / thinking
Passive – waiting / non-thought (not necessarily active)

	Time	Thought	Need	Future
Predictive	Projective	Some	Within	Future
Reactive	Immediate	None	Within	Present
Proactive	Anticipatory	Much	Across	Future +
Passive	Latent/delay	None	Across	Present

Figure 3. Analysis of types of Human Refinement.

The taxonomy of the user roles, is based actions provided to the user. The actions are a result of the fusion system interface and should be designed into future fusion systems so as to accomplish the ontological goals of the system.

While the paper addresses many ontological questions concerning the human interaction with a fusion system, there are some other issues associated with the inferencing issues: such as semantics, taxonomy, and efficacy of results.

4.2.2 Display / Interface

The display interface is key to allowing the user to have control over the data collection and fusion processing. [18] Without designing a display that matches the cognitive perception of the information, it is difficult for the user to reason over the fused result. While many papers and books address the interface issues (i.e. see multimodal interfaces), it is of concern for the fusion community to address the cognitive user issues to ensure that the fusion system designed is to emulate the functional roles required of the fusion system.

4.2.2.1 Semantics

Developing a framework of a user refinement system must have some sort of semantics or interface actions that allow the system to coordinate with the user. Such an example is a query system in which the human seeks questions and the system translates these requests into actionable items.

4.2.2.2 Efficacy

Efficacy is an important concept for the ontological questions involving a human and a computer system. If the user has confidence and reliability in the fusion system, the fusion system will be further utilized for it s capabilities. Without having trust in automation, the effects of the inferencing over the data will not result.

4.2.2.3 Taxonomy

A taxonomy [19] is a classification of something – such as algorithms, processes, and things. In order to execute the prioritization information, there has to be some sort of classification. The difficulty is that each user, unless trained, sees the world slightly differently and thus, has a different classification for objects and processes. In order to develop efficient and effective fusion systems, it is important to develop a taxonomy that relates to the ontological perspectives of what the human expects in the world. Such an example is tracking a target. The expected processes are detection, recognition, classification, and identification. If the object is identified, then it is assumed that the target is detected and not the other way around. Seeking a valid taxonomy of objects and fusion strategies will help the user in determining what role they should play in the active reasoning over data and fused information.

5 Conclusions

As presented in this article, data fusion involves the integration and application of many types of data and processing techniques to satisfy a user need. The paper described various taxonomies of terminology to further the ontological questions. The ontological questions surrounding a fusion system's ability to provide knowledge, requires a consistent ontology, epistemology, and pedigree information. As a summary, Figure 4 shows the relationship between the ontological issues of deductive logic about the knowledge in the world and the inductive logic, from fusion of observations about the

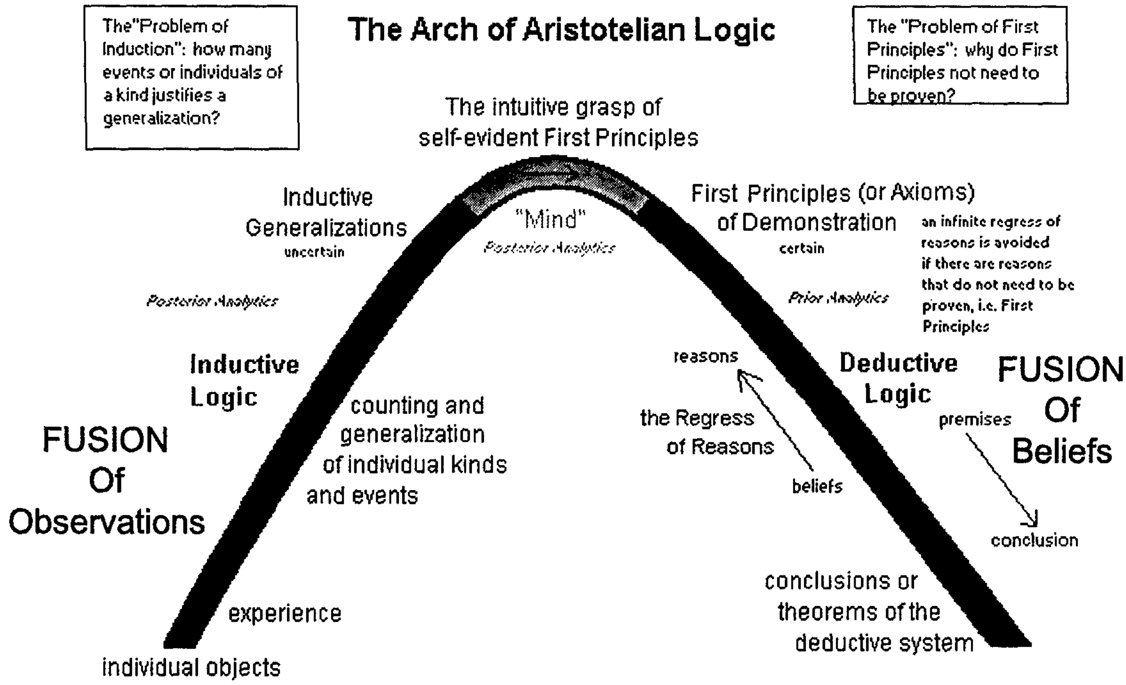

Figure 4. Ontological Explanation of human refinement of information fusion.[20]

world. It is in the mind of the user in which an intersection occurs. The data observed and the models processed need to be of value to the user for effective fusion system designs. Future research will involve extending the taxonomy and ontology to situational awareness[21] to integrate the human and fusion system attributes.

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