The Effect of Avicenna's Philosophy on the Development of Cognitive Architecture for the Network Centric Command and Control

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***Abstract* – This paper surveys the effect of Avicenna's self philosophy on the development of cognitive architecture in Complex Adaptive Systems (CAS) like the network centric command and control. Initially the role of Popper's three world theory for specifying the ontology of the CAS extent and specially the usage of that in the development of the semantic architecture are defined. Afterwards, the Avicenna's self philosophy and its role in specifying the cognitive aspects will be determined with an applied approach. In fact, on the one hand it is shown that the CAS cognitive extent is made by two cognitive aspects, individual and social, and on the other hand the role of abovementioned philosophy in specifying the cognition process specially in the sense making process from the network centric Command and Control (C2) is defined. With specifying and assertion of above specifications, now the Popper's three world theory is developed and the Avicenna – Popper's three world ontology for the CAS will be concluded. As a matter of fact, it is shown that the semantic architecture for the distributed C2 is made of physical, informational and semantic (individual and social) extents and specially the cognitive social and individual aspects and their relationship with Avicenna's first and second intellectual concept will be concluded.**

***Keywords* – Ontology, Avicenna's self philosophy, Cognitive architecture, Network centric C2, Popper's three world theory**

I. INTRODUCTION

Iranian Philosopher, Avicenna, has various interests and theories in different fields. He has theories in self philosophy and for accomplishing Aristotle's philosophy that can be used for developing the cognitive systems in this age. The Avicenna's holistic philosophy has demonstrated self existence and unique entity and has envisioned various forces and different tasks for that. After he describes cognition and its types, he explains its forces and also these forces' tasks. Therefore Avicenna achieves the cognition procedure, forces (process) and tasks in the human self, the procedure which was pointed out a thousand years later [1], [2]. The theory that Avicenna has shown for cognitive and different forces for processing knowledge can still be used in the brain architecture and it has a radical significance in the development of the CAS which humans have had critical roles in them. Nonlinearity of these systems causes problems for understanding the existent situation and separating their different aspects.

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The architecture of the systems like distributed C2 is of broad type [3], and without attention to the operative philosophical and scientific basics, rendering a correct and fruitful approach for their architecture is impossible. On the other hand, resorting to depletive and incidental approaches creates diverse and fundamental effects and leads to deviation from our main goals. Without a global vision, it is not possible to understand all necessary elements together and their interactions and define their correct classification. The new holistic philosophy discredits depletion and develops paradigms, theories and tools for identification of a system as an integrated whole. Specifically, it has a vital significance in recognition of distributed C2 which is looking for a collaborative and collective view of all main aspects of sense making process [4]. Incidental viewpoint which is deduced from rejection of holism cannot recognize the differences between entirety and incident, the differences which belief in them has a direct consequence on the development of different parts of a system and can be seen in specifications, rules and elements of the system.

Ontology concept is one of the most recent significant developments in the effect of philosophy on the engineering systems and especially on the development of soft and complex systems. Ontology is a formal description of a shared conceptualization which is readable by the machine [5]. So ontology directly converts the concerning concepts in the philosophy domain to the implemental concepts. A property of a conceptualization is identifying the shared knowledge which the foregoing ontology carries it. Although ontological approach is not the only way for conceptualize but this way with expressing formal terminology, represents properties for sharing knowledge in the development of the intelligent software. These properties contain semantics which are separated from reader and background. Practically, ontology implementation creates bonds. In fact, ontological necessity means agreement on the terminology of that ontology for using query and making required demonstration. The important point is that an agent in social systems has implicit and explicit visible ontologies which are meant its fidelity in conceptualization of corresponding ontology. Implementation of new holistic philosophy concepts and its semantic tools like ontology determine that the related concepts of complex systems in this age and philosophical concepts are together and could not be separated easily. In fact, their separation increase s complexity and specially slows the knowledge - representation integration processes down.

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At first, the effect of ontology philosophy on soft systems like intelligent and semantic systems are defined and the necessity of attention to the philosophical paradigms for the development of the CAS systems are defined. Then Avicenna's philosophy with emphasizing on its cognitive aspects is specified as a holistic philosophy and its main specifications are determined. By using this philosophy and gathering it with Popper's philosophy the paradigm of the three worlds theory with emphasis on the conceptual models is introduced and in continuance the effect of that on the development of the distributed cognitive C2 is shown and development of the decision systems and architecture models will be determined. In the conclusion section and future work, specified results and future works especially in the non-cognitive aspects of specified paradigm will be presented.

II. THE EFFECT OF NEW HOLISTIC PHILOSOPHY ON THE NETWORK CENTRIC C2

Of the main results of new holistic philosophy is denying Positivism and Behaviorism which the insight based on these two, cannot cause the development of the CAS systems like Network Centric C2. Positivism doesn't emphasize on the observer consciousness and ignores believes, values and its type of view to the world around. Of its significant results, is emphasizing on the observation and doesn't attention to the consciousness interpretation which are meshed with this observation. Also attention to behaviorism, disregards intrinsic feelings and cognitive aspects. Therefore, emphasizing on the positivism and behaviorism toward data enforcement is per se separated from aim and intention which increases the technology rule against attention to the human and different cognitive aspects. This conclusion contradicts the Network Centric tenets in the development of distributed C2.

Positivism and behaviorism refusal and in fact implementation of new holistic philosophy, is concurrent and in parallel to development and extension of four cognitive aspects of purposefulness, critical thinking, consciousness models and cognition theories in last decades [6].These have been effective on knowledge-based responsibilities like decision-making model. Purposefulness results in direct development of desired model based on command intentions and aims. Critical thinking develops the status model not directly but in relation to aims and consequently in relation to desired model. One of the results of this approach is the omission of irrelevant and unnecessary information which eliminates the contamination of information for rapid and correct decision making. The role of consciousness models for development of desired and existent status models makes the decision making phases to distribute effectively and everything develops like human consciousness. This is particularly in relation to cognition of complicated processes like sense making which is impossible without usage of consciousness models and cognitive phases.

Ignoring the cognitive aspects can eventuate in determinism which consequently results in not paying attention to the relation of the whole and the part simultaneously and with each other. With such a viewpoint, attention cannot be paid to the collaborative interactions while considering the self-rule of individual aspects. Therefore, this approach threaten the network centric tenets for the development of the distributed command and control and subsequently makes the development of the self-coordination in the basis of the development of the local interactions impossible. The development method of self-coordination of distributed C2, is made from the development of the local interactions which is obtained from a nonlinear understanding of distributed C2. In this process the self-rule of elements (talents and individual abilities) can be used for the development of the various local interactions and this will result in the general novel behavior which is the basis of the self-coordination for controlling C2.

Another result of using the new holistic philosophy is attention to the universality of C2 as an independent existence apart from its components. This kind of result can't be abstracted in the developing of one or more general products or procedures. These products or procedures should contain all main components of the architecture and influence all of them. In fact, while the universality of C2 should be the assembly of different components with specific relations, the aforesaid procedure should also be the assembly of different components and relation between those. Sense-making process in the distributed C2 has such a role. Although this procedure has all main components of the architecture also introduces the relations with each other. Such a process opposes behaviorism and positivism. Sense process on the one hand and extraction of data, information, knowledge and belief and their fusion on the other hand create sense making cycle. These two procedures simultaneously create the sense making cycle similar to sense making cycle in the human being. Therefore, not only the necessity of sense making as a cognitive approach and by denial of behaviorism is determined but also this process in network centric C2 is created as a general procedure which contains all the main components.

Another significant point which is defined the necessity of the new holistic philosophy, is denial of the detailed view. Denial of detailed view cause the attention to the whole as a separate entity from components and understanding of the differences between the two in the three sections of attributes, principles and finally ontology. The differences of whole attributes separated from components attributes could be seen in a chemical reaction of sodium chloride which is an eatable product produced from two poisonous components, sodium and chlorine. Distributed C2 has self-synchronization property which is created from sense making and contains cognition as a down-top approach and concurrent with data extraction that could not be created with any of the physical, informational and cognitive components alone. The principles of whole are different from the principles of components. This case can be seen in the generality of social network C2 which is different from the principles of local interactions. Existence of new components in the whole without being existent before defines its ontological difference. In the act of fusion like information fusion, knowledge will be created which is new and has not been existed before [7].

All the above-mentioned subjects show the role of the new holistic outlook in cognition of complicated phenomena like distributed C2, and defines that different aspects of this

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cognition create an opportunity for holistic based methodologies to be introduced making use of them. The holistic methodology which is against reductive methodologies, studies, architects, designs and analyses the whole separately from the components. In a reductive methodology, components, parts and their relations is studied, analyzed and designed while do not consider the whole as a separate entity from the parts.

III. PHILOSOPHICAL PARADIGMS AS ONTOLOGICAL THINKING

Understanding the role of holistic philosophy in development of complex systems like distributed C2, now in continue, it is logical to search some reasons to apply different aspects of this philosophy. Defining and using philosophical paradigms is one of the methods of applying different aspects of holistic philosophy. A paradigm is mentioned in a frame of a confident clause containing philosophical results with an extended and definite effect domain. These paradigms display our general attitudes and approach and express philosophical orientation in certain fields. Because of the relation between those paradigms and philosophical concepts, we understand their ontological tendencies. So, considering that ontology is a philosophical concept from the available subjects and is a framework to determine a certain area of the world, each philosophical paradigm expresses an ontology in its philosophical meaning.

One of the most important points in modern holism is attention to the truth as some uncertain, objective, real, and obvious theories which are against certainty and surety. Thus, searching for truth, human encounters various faults and problems because of his limits. So all of his theories are fallible and uncertain, and must always try to struggle against those faults. The main point is that he will never reach to a complete certainty. Faults occur when we think we have achieved a complete and fault-free understanding. We should try to get closer to objective truths and to avoid absolute ones. This is the reason why scientific theories are imaginative and they are based on some revocable assumptions. Attending to scientific theories are based on imagination or postulates. Indeed, postulates show our assumptions in the related area, which they in turn have a root in philosophical paradigms. By postulate method we can use different paradigms and then different philosophical results and effects during different periods.

Recognition and utilization of complex fields like distributed C2 without using philosophical paradigms is difficult and thus we cannot use them operationally. In the fields like C2, some different components have been used which have non-linear relations with each other. Without attention to philosophical paradigms like parity principle, one neither cannot understand the relations between the parts and the whole nor realize various differences between them, and without attention to these philosophical paradigms one cannot understand development of new attitudes and so cannot utilize the different parts to develop these attitudes. Recognition of disorder components or lever points [8] in non-linear systems like distributed C2 is one of the main duties that we cannot control system divergence and use convergence toward the goals. Therefore, philosophical paradigms are one of the main aspects for identification and development of complex systems like distributed C2 which one cannot reach to the desired results without them.

In artificial intelligence field, ontology is an explicit and formal feature of a common conceptualization [5]. And a formal conceptualization is a demonstration of knowledge of a desired area containing concepts, objects, or classes of them, and other available entities together with the relations between them [9]. In fact, this conceptualization is a simplified and abstract view of the fields that we desire to demonstrate, and the used concepts create some words in it so that a machine can read them. Thus, ontology as a philosophical concept converts to an engineering concept that can be either implemented on a machine or is reusable as a formal, abstract, logical and soft component.

One of the most important reasons for utilizing ontology rather than demonstration of knowledge is its usage in understanding complex environments. Understanding process in human not only is a complex phenomenon but also its concurrent utilization feature in human duplicates its complexity. In understanding process, in addition to clustering of the concepts in different abstract levels, creating various interpretations also plays an important role [10]. Ontology is one the main elements in creation of these interpretations. Indeed, each interpretation means execution of a mapping between various concepts of abstract levels in mind which each one is defined in a different ontology. Thus, in developing sense-making procedure of distributed C2 in which understanding is one of its most important processes, utilizing ontology can be very effective.

Another important advantage that identifies utilizing ontology in complex systems like distributed C2, is attaining briskness which means execution with high speed and intelligence concurrently [11]. Data, information, knowledge, and belief fusion play a fundamental role in sense-making procedure of C2. Information fusion was introduced as a catalyst in the second idea of network wars and is on the principle that we can produce boosted and common information. Sense-making is based on knowledge fusion and the beliefs related to deep distributed awareness factors. When fusion is based on ontologies with equal backgrounds, then to combine them there is no need to background relative decontextualization process, and they merge together quickly [12]. In addition to word level, this combination is taken place in semantic level and therefore intelligence and briskness are both utilized.

IV. THREE-WORLD LEARNING PARADIGM AS DISTRIBUTED C2 DOMAIN ONTOLOGY

Three-world learning are taken from Popper philosophy [13] which we combine it with Avicenna’s philosophy and make it more exact. In first world extent, the main activity of living beings is toward problem solving; solving of problems that are constantly associated with testing, finding, and error minimizing. And this means, of course, mutual impression of living beings with their peripheral world. In this mutual impression, sometimes veins of awareness display themselves. Popper's second world was the living field of evaluative and cognitive awareness or awareness related to problem solving. Problem solving activity has

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belonged to the first world that has now come to the second in the form of awareness. When he talks about third world, it includes all scientific and engineering products, and this world, in fact, is sum of awareness and life. Products of this world have been formed by utilizing awareness. Thus, we can call the first world as senses and physical world, the second world as mind and knowledge world, and the third is those products that are produced applying the second world capabilities to the first world problems. The important point is that the elements of the third world are interacting with the second world elements directly and with the elements of the first world indirectly through those of the second world. Up to now, we can apply three-world learning to a whole and find out about its three main components: the first world one that is a physical component; the second world one that is a cognitive component; and the third world one that is an information component. A problem or duty is propounded in the first world, which is solved by the abilities of the second world, and the results are given to the third world. The point is that the product in the first world after production is considered as a sensible one and is assumed as a part of a problem in the first world. Hence, this learning makes a cycle that makes a repeating process of problem solving.

The root of this Popper's division is in the separation of Aristotle about existence and essence of things [14]: 1) The sensible and permanent existence like stars and sky, 2) The sensible, temporary, impermanent, and mortal existence like plants and animals, 3) The motionless existence that is insensible but exists. The two first and third Popper's worlds are from senses types that are corresponding to the sensible, permanent existence and temporary, impermanent existence. The motionless existence is equal to cognitive aspects. In Popper's division, human place is determined and a part of the motionless existence which is related to humans and is separated as the second world, that can produce sensible, impermanent products titled third world. Thus, in CAS (Complex Adaptive Systems) ontology, because of stipulating the role of human, Popper's division is more applicable than Aristotle's division.

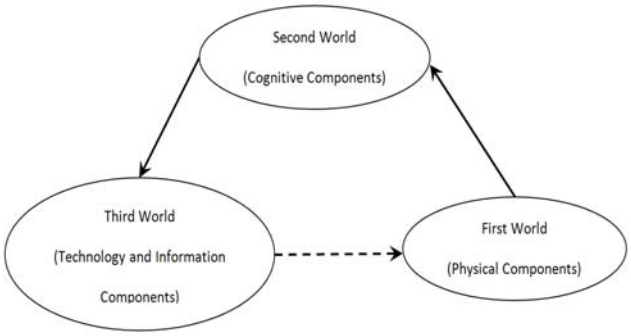

Figure 1: Popper's three-world learning.

Three-world learning is an answer to a basic question that separates three philosophical schools of ultra-realism, conceptualism, and nominalism. This question is related to general names that whether they have either real evidences or specific pictures like specific names. In other words, whether each general name requires a general subjective existence from one side and a general objective existence from the other side? Ultra-realists believe in a total image from a general name that requires a total and objective existence. Whether or not this total existence is in senses is the origin of difference in this philosophical school.

Plato defines senses world for trivial affairs and real world for objective and external totals. Conceptualisms like Aristotle believe that the general name denotes the total image, but the total image has no objective and external similar. This concept is merely a subjective product that is produced by common understanding in details. Detailed phenomena are not completely separated and have some commons from which a total image is appeared in the mind. In nominalism school, general name indicates neither total image nor objective total existence. Each total image is the general name that is a product of human naming. Each of us is an individual existence and selects a name for each phenomenon we encounter. Commonality in phenomena causes a common name which is the basis of mental concepts. Thus, three-world learning is a kind of answer to ultra-realism form that knows technologies and information components as objective entities of general names and accepts existence of mental total components for them. Figure 1 illustrates Popper's three-world learnings [13], [15].

The first world has a longer life than the two others and, in fact, comprises all physical components. During its evolution, in a period of time, the second world, which really is the world of thought and awareness, was born together with creation of human. Appearing this world, changes of the first world in those fields that human interferes, have become more complex. The third world is created upon utilizing this thought and awareness on the first or physical world, which comprises different technologies including soft and information technologies. The important point is that the third world, after creation, can itself be a part of the first world, and an intellectual processing can be done on it. The above conceptualization can be utilized in development of real and virtual architectural ontologies of complex domains like distributed C2 if combined with Avicenna's philosophy of about human self being. This can particularly be effective for assertion of understanding process in such systems.

V. COGNITIVE FEATURE OF AVICENNA'S SELF PHILOSOPHY

Avicenna was an Iranian philosopher of the third century of Hegira, with cognitive and holistic desires and theories, who could complete Walker Philosophy, and criticized and developed a large part of Aristotle's thoughts. His role was specifically on separation and classification of mental concepts which can be used for completion of three-world learnings. Avicenna is one of those theoreticians who emphasized experience and action. From the Avicenna's specifications are his pluralistic thoughts that cover various fields. He passed from Aristotle's and Farabi's interpretation and returned to authenticity of his statements in philosophy. Some of his desired fields were medicine, theology, music, astronomy, geometrics, logic, realism, ontology, politics, education, art, sports for juveniles, and human psychological and cognitive features. In fact, upon his holistic view, he could use together Islamic theology, Iranian old religions, Farabi's and Aristotle's philosophy, logic of Baghdad and Stoics schools, Plato's ontology and cognitive science,

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Galen's psychology, Plato's politics, Euclidean and Ptolemaic astronomy. He also understood the reality of fossils, invisible things in water, the importance of food diet, and psychological diseases. In his philosophy, he could combine his semi-Aristotle philosophy with mystical features of intuitionism. One of his anthropological theories, which was the root of Deckard's thought, was his suspension human that displays human self-awareness power even in vacuum and an environment that has no connection with its peripheral world.

Avicenna has a holistic theory about general names and their connection with external evidences and general mental images. His thinking shows his strong understanding of the connection between the whole and the part. Avicenna has accepted either inclusion of mind on general images or general and objective existence as external evidences of general names. He believes that general images come from mental activities on detailed affairs and each detail has a share from the whole. He says that total images are in human mind and objective general existences are in God, and there are some gains of whole in the parts. The core of Avicenna's thought is defined as: "What the whole is, is inside things, is before things, is after things, and is extremity of things. It is inside things because existing common features in things is an effect of the whole. It is before things because it is ever lasting in the world. It is after things because it moves to human mind from things and is identified with a name." So, we find the whole and the parts simultaneously which their separation is a hard work. In addition, he splits general thoughts into two parts: first and second intellectual concepts. The first intellectual is a general concept which is formed by commons of senses and details, like color and shape. The second intellectual is a general concept which is formed by comparing other concepts, like detailedness and otherness.

In the first intellectual concept, comparison is occurred in senses world, but in the second, comparison is occurred in mind. Thus, about one thousand years ago, Avicenna had understood separation of different fusion actions either in information level or in knowledge level, which is from the most basic steps of sense-making process in network centric C2. Figure 2 illustrates this concept.

Avicenna's correct understanding from human mind and his extended and multidisciplinary view causes his theories seem in advance of his time. And it is the reason that a lot of them are still ambiguous. Avicenna has criticized Walker Philosophy and has combined philosophy with mysticism and intuitionism. The various abstractions that he produces from mind in the form of theoretic Intellectual concepts, displays his philosophical abilities. The apogee of this philosophy is shown in "Salaman & Ebsal story", which was represented by Khajeh Nezam-ol-molk Tousi, and contains various effects of mind and intellect in frame of events [16].

From the main specifications of Avicenna is his attention to self which, in fact, displays his interest in different cognitive features. On the other hand, he has excelled over Aristotle in study of self and has concluded various innovations. His "Esharat and Tanbihat" [16] and "Self" [17] books demonstrates his specific believes and various innovations. From presumptions of Avicenna is uniqueness of self which doesn't separate self of heaven, plants, and animals from human self and considers them in an extended architecture as the components of an unique whole. This presumption is also seen in modern mind architectures from [18], and [19]. Avicenna says the most apparent understanding for human self is his self, which includes two understandings of self imagination and its existence confirmation. He concludes this in four states of wakefulness, sleeping, drunkenness, and human suspended in space. So, self is a truth in human which we can understand it directly, while other truths can be understood by various senses and perceptions. Proving self truth as an entity in human, now Avicenna proceeds with the question that what the receivers (sensors) and causes of this perceptions are. The suspension human assumption says that ordinary senses have no role here and we should find other sensors. Avicenna distinguishes receiving and storing (memory) powers in two categories of outward and inward. He also splits inward power into direct and indirect parts, which the first is for all animals and plants including human, and the second is pertained only to human.

One of the basic works of Avicenna is that he demonstrates various situations of self and its connection with body. The first part is those situations that are necessary for body such as sleeping, wakefulness, health, and illness. The second part is those situations from self which participation of body is low in them such as fear, horror, imagination, anger, and grief. Connections between self and body are from those fields that Avicenna had used in his medical treatments [20].

Sense-making process is the most important one in network centric C2, and while it is not developed up to an acceptable level, neither operational planning is formed nor operations are executed. The important point is that sense-making process has begun from necessary data, information and sciences extraction and their fusion, and continues till attainment of deep awareness. Figure 1 illustrates this problem. Fusion of signal, data, information and various believes is taken place and all of them continue in pace with a common situational awareness and sense-making. The important point is that the process continues after decision-making and operation execution, and takes its feedback from action field, and perception process becomes more completed. Thus, perception process is a down-top process which occurs in human mind to understand a complex situation like distributed C2. In the understanding path, Avicenna has acted more specifically and has separated four situations of sense, imagination, hallucination, and thinking at first. A thing is sensible when it is seen, and is imaginative when it is not seen but is present in mind. A thing is hallucinatory when it is insensible and immaterial (implication), and is rational when we understand human intellectual. When a human becomes sensible, some of his symptoms surround his mind which their elimination has no effect on his humanity nature (such as situation and quality). Imagination takes place when there are not sensible symptoms. Hallucination is occurred in partial concepts and it does not include far symptoms (such as paternal love). Real abstraction occurs in rational state. This is a general concept and details and symptoms are not considered. Thus, the goal of each abstract perception is up to thinking to understand the nature of environmental phenomena without peripheral symptoms.

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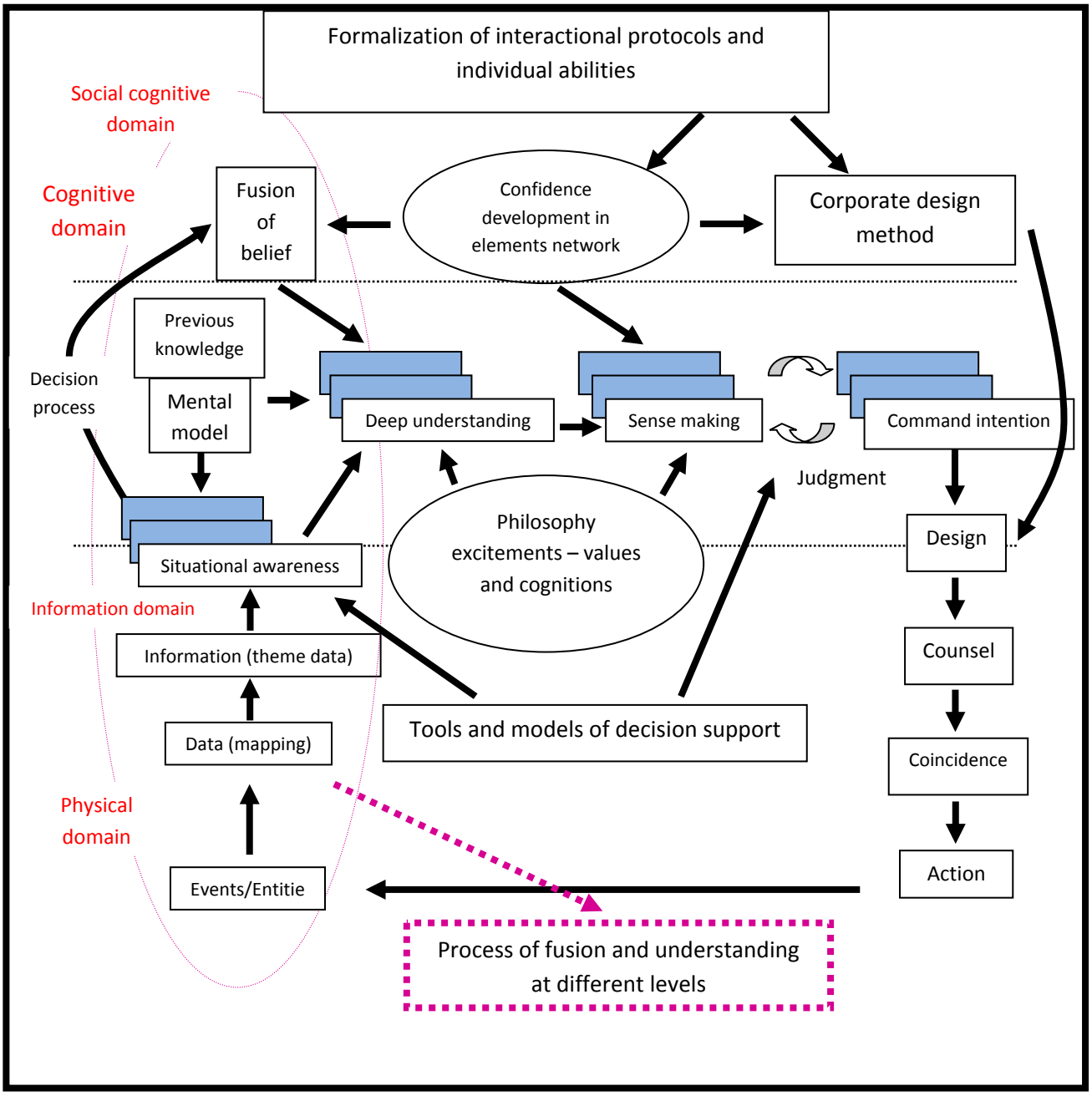

Figure 2: Conceptual model of sense-making cycle.

Therefore, Avicenna describes understanding process more specifically than modern models like JDL [21]. A model like JDL begins from sensible signals and data, extract and fusion them, and continues to information, knowledge, and various beliefs. The very important point in Avicenna's reasoning is to determine detailedness or generality of understanding stages, which is exactly equal to making or not making fusion in sense-making procedure of network centric C2. Fusion occurs when the known or desired goal in general. The other point is that from the four states of sense, imagination, hallucination, and thinking, three of them, namely sense, imagination, and thinking can be used on an entity and increase abstract levels gradually. Imagination is isolated from the other three and is used separately. The last point is that thinking is isolated from material and immaterial intellectual concepts, so we conclude two categories of first and second intellectual concepts. If the intellectual concept is material, it will be sensed at first and then it will be imagined by common sense in absence. Then it will be abstracted by intellect and will be emptied from details and far symptoms, and will return to a general concept and without specifications. In the second category, intellectual concept is an immaterial event which it has no need to intellect and its abstraction. This category is a complete one in its intellectuality and there is no way for sense and imagination in it. Belief fusion is occurred in this level and the second intellectual concept is resulted.

Avicenna's innovation in extraction and collection of data and information is due to a common power in all animals. This extraction begins from a scale in signal level and continues up to obtaining intellectual concepts. This scale, which there is not even in initial JDL model [21], can reveal Avicenna's meticulous view in about one thousand years ago, which can still be used in higher levels of intellectual concepts for abstraction. Avicenna's model begins with sensual receives and the received features are identified. Avicenna mentions these received features by ordinary

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senses (such as eyes) similar to points of a line that remain in a certain location of mind and the line will be understood by attaching the points [16].

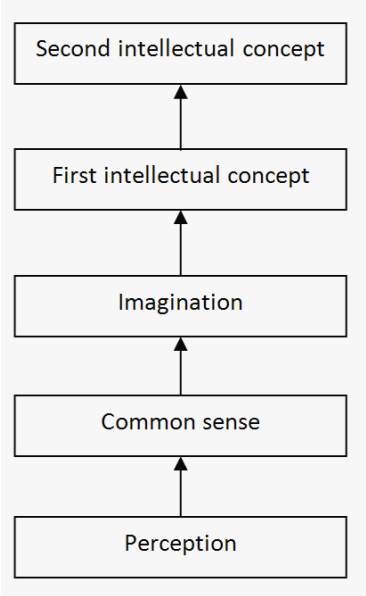

Figure 3: The procedure of generation of first and second intellectual concepts in Avicenna's model.

Thus, this is equal to extraction of signals and its fusion, which is titled J0 in JDL model. When the senses are extracted in frames of features, they will be fused together by a force that is inside body power. The important point is that Avicenna promotes the five outward powers to eight, and in fact, he splits touch sense into four mutual categories as cold and warm, wet and dry, fine and coarse, and finally solid and soft [16].

Following that, Avicenna mentions some insensible powers and calls them inward properties which are supported by psychic devices. The first one is insensible meaning perception power which is called common sense or "bentasia" and is supported by a device at the first of the brain. In experience of each living creature from the features fusion (signals) in data framework, an entity with a specific meaning is created (data) which, after saving, can be used in future experiences. And now, by Avicenna's interpretation, self with a common sense judges among data. The instance, "This white thing (for example, sugar) is sweet" is an application of common sense, which adds whiteness and sweetness as an optical sense and a tasting sense, respectively. The important point to prove the existence of common sense is the presumption that no power can either understand two senses simultaneously. So, no body power can result two data simultaneously. Then, it is necessary to have a power for common senses. Avicenna has generalized this presumption as a single rule, that each power is either receiver (sensor) or saver (memory). It should be noted that, from Avicenna's point of view, this common sense is a receiver power that, in fact, does data fusion. After common sense, this is imagination that its device is located in the first brain abdomen, especially in its lower part, and saves the result of common sense. Hallucination is the next power that its device is the whole brain; however, its specific location is in the middle abdomen. This power is a receiver, and its role in all animals resembles its role of intellect in human, and the effective domain of both is the whole brain. Avicenna mentions a power that fuses sensible perceptions and insensible meanings, or separates likewise fusions, vice versa. This power can take place either by hallucination or intellect (in other words, it can be used either by animals or by human intellectually).

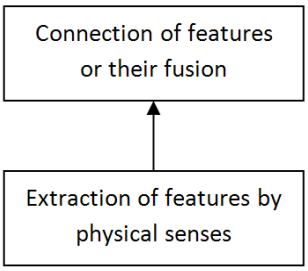

Figure 4: Outward sense procedure.

If hallucination uses it, it is called imagination, and if intellect uses it, it is called thinking. Avicenna calls both imagination and intellect powers as possession, which are serving hallucination directly and is connected with intellect by hallucination. The other power is recitation power that is a kind of memory and is located in the last abdomen of brain. Its relation with hallucination is similar to the relation of imagination with common sense. Therefore, Avicenna has identified inward self powers (common sense, imagination, hallucination, possession, and recitation).

VI. EFFECT OF AVICENNA'S SELF PHILOSOPHY ON DEVELOPMENT OF THREE-WORLD LEARNING ONTOLOGY

Figure 2 illustrates three-world learning and its three main components and their relationships. Thus, general ontology of each adaptive complex system in which human has the main role has three main components that the general relation between them is known. Obtaining the above information as an intelligent architecture of each type of CAS (like network centric C2) using above-mentioned learning is so general and coarse. In this chapter, we develop this ontology, using a cognitive approach from Avicenna's self existence philosophy. The most important part is the development of the second world component which represents thinking power in human self.

In Avicenna's innovation, this world comprises two first and second intellectual concepts, which the first begins from the entities of the first world and reaches to the intellectual concept by refining symptoms and details. This component represents individual cognitive component in which sensible symptoms and details of related individual are omitted. Second component of the second world is about second intellectual concepts, which is an abstract of first intellectual concepts. In fact, this component represents integral cognitive component which fuses two or more first intellectual concepts and an intellectual concept at the uppermost level is extracted. Thus, in the view of Avicenna, social component is a kind of cognition in integral field. The important point is that to extract first intellectual concept, we should start from the first world or sensible world, but second intellectual concepts start from first intellectual concepts without any need to sensible and material details.

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Another part of modification in three-world learning occurs using Avicenna's self philosophy in physical and information world or first and third world with regard to understanding process. In conceptual model of Figure 2, understanding process location in sense-making procedure is illustrated. This figure shows understanding from different abstracts together with five fusion in signal levels (events in physical world), data level, information level, knowledge level (locational awareness), and finally beliefs in confidence networks. The two knowledge and belief fusions in the second world are as first and second intellectual concepts. And the first fusion in signal level is, in fact, the features fusion in Avicenna's self model, which uses outward or physical senses to extract required data. The common sense power in human and animals represents data fusion which needs imagination component to save resulted information. In figure 2, neither we have imagination component nor different states of information fusion. This is important because we are looking for developing of sense-making process of intelligent architecture of distributed C2 based on applying excitements to it. In fact, we understand the essential role of excitements to obtain the intelligent architecture upon acceptance of Damasio's error paradigm [22]. So, without applying excitement in architecture of CAS systems like C2, one cannot obtain intelligent goals. Avicenna considers excitements and senses with imagination and hallucination. In addition, he separates the touch sense from the others because it generates different feelings in four categories like cold and warm, wet and dry, fine and coarse, and solid and soft, and add them to body senses. Imagination is the memory for common sense power that saves data fusion output. In fact, imagination includes insensible information with far symptoms and details. Insensibility of imagination makes it usable in various experiences, and therefore is the base of scientific and artistic innovations. After imagination, it is hallucination that, in fact, is insensible information without symptoms but with details. Table 1 shows this information. The important point is that because symptoms are separated from it, then it can be used in every field. Thus, Avicenna concludes that hallucination in animals play the same role as intellect for human, and its location is the whole brain. A hallucination comes from fusion of sensible receives and insensible intellectuals, which is saved in recitation memory. Hallucination action in human can be also done by intellect, which Avicenna calls it thinking, and recitation is its saving location. Table 1 shows all the above components.

The most important modifications in network centric model C2, are determination of cognitive component in two subcomponents of individual cognition and social cognition, which in a cognitive approach are equal to first and second intellectual concepts according to table 1, respectively. The second is to determine and separate two kinds of information, one from common sense and the other from hallucination. Therefore, we can modify three-world ontology based on the contents of table 1 like figure 5.

Table 1: Components of Avicenna's self model.

No	Component	type	Specification
1	Outward senses (physical)	Perceptual-memory	Sensible, with far symptoms and details
2	Common sense	Perceptual	Outward senses output
3	Imagination	Memory	Insensible, with far symptoms and details
4	Hallucination	Perceptual	Received from outward senses and insensible imagination
5	Recitation	Memory	Received from hallucination (insensible, with details and without far symptoms) Received from intellect (insensible, without details and with far symptoms)
6	First intellectual concepts	Perceptual	Received from inward and outward senses
7	Second intellectual concepts	Perceptual	Received from first intellectual concepts

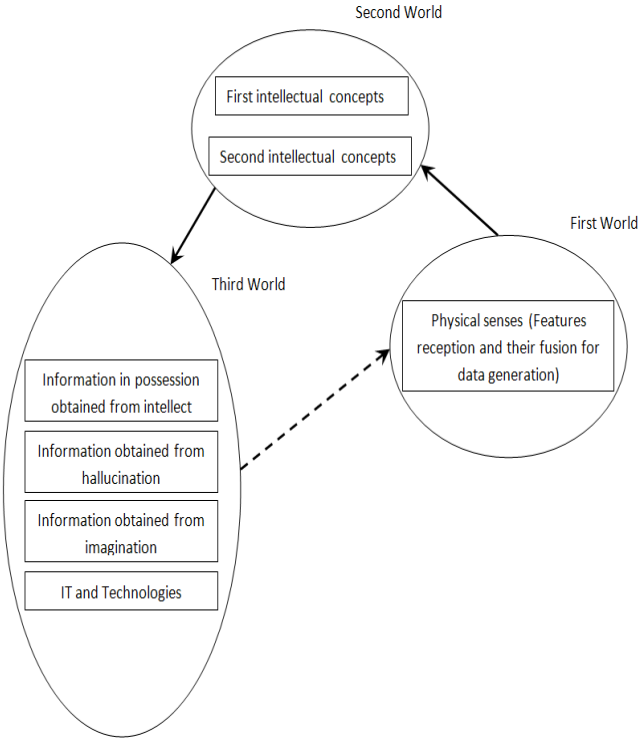

Figure 5: Popper-Avicenna's three-world learning.

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VII. CONCLUSION AND FUTURE WORKS

Popper's three-world learning can classify those adaptive complex systems that human interferes, into three components; the first world that includes physical components, the second world that includes awareness and thinking and, in fact, includes cognition component, and the third world that represents utilizing human awareness on components of the first world, and produces different products from various technologies and information technologies. Thus, using this learning on any CAS system like network centric C2, one can obtain intellectual architecture with three physical, cognitive, and informatic components. The above learning is very coarse, so they cannot represent ontology to determine network centric architecture C2 merely based on its information. Avicenna's self model as a whole is exactly on parallel with three-world learning, which utilizing it, each world in this learning is identified with detailed components. The important result is that all these components can be utilized to develop conceptual model of sense-making process in network centric C2. The physical senses component is identified in the first world, and receives signals and fuses them into certain data. In the second world, two components of first and second intellectual concepts are corresponding to individual and social cognitive components, respectively. And finally, the third world includes technologies, information technologies and information from common sense power (imagination), hallucination, and detailed insensible information without intellectual symptoms.

One of the most important future works is development of Popper-Avicenna's cognitive ontology along with second intellectual concepts. These intellectual concepts are obtained from first intellectual concepts, and do not deal with physical or detailed sensible and with symptoms phenomena. The cognitive intellectual concepts with integral features like confidence and necessity are of this type, which determination of their types, utilizing them in social networks and promoting them are from the future features can be considered for ontology development. Another future work is determination of different elements in the third world, which, in fact, are created from awareness element of human in the second world. These elements like different philosophies, sciences, and technologies not only should be identified but also their influence on development of the desired domain and development of understanding process should be studied.

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