World Academy of Science, Engineering and Technology
International Journal of Computer and Information Engineering
Vol:17, No:2, 2023

The Nature of Intelligence and Its Forms: An Ontological-Modeling Approach

Husam El-Asfour, Fateh Adhnouss, Kenneth McIsaac, AbdulMutalib Wahaishi, Raafat Aburukba, Idris El-Feghia

***Abstract*—**Although intelligence is commonly referred to as the observable behavior in various fields and domains, it must also be shown how it develops by exhibiting multiple forms and without observing the inherent behavior. There have been several official and informal definitions of intelligence in various areas; however, no scientific agreement on a definition has been agreed upon. There must be a single definition, structure, and precise modeling for articulating how intelligence is perceived by people and machines in order to comprehend intelligence. Another key challenge is defining the different environment types based on the integral elements (agents) and their possible interactions. On the basis of conceptualization, this paper proposes a formal model for defining and developing intelligence. Forms of intelligence are derived from an ontological view, and thus intelligence is defined, described, and modeled based on the various types of environments.

***Keywords*—**Intelligence, forms, transformation, conceptualization, ontological view.

I. Introduction

ONE of the eminent long-term goals of artificial intelligence is undeniably and by-far geared towards a comprehensive understanding and thus developing concrete foundations of intelligence. In the last few decades, there have been many formal and informal definitions of intelligence in various fields, including computer science, psychology, and philosophy. There is no universally accepted definition of intelligence among researchers and scholars. However, the core semantic of the intelligence concept and the inherent characteristics share some common features and properties amongst researchers and scientists in various domains.

Higher-level abilities (such as abstract reasoning, mental representation, problem-solving, and decision making), the ability to learn, emotional knowledge, creativity, and adaptation to meet the needs of the environment have all been used to characterize intelligence in various ways. Alfred Binet, a French psychologist, and his colleague Henri Simon began working in Paris in the early 1900s to establish a test that would distinguish students who were supposed to be better learners from students who were slower learners [1].

The psychologist Charles Spearman theorized that there must be a single underlying construct that combines all the abilities and skills measured on intelligence tests: the general intelligence factor (g). Almost all psychologists believe that a general intelligence factor, g, is associated with abstract thinking and encompasses the ability to acquire knowledge, reason abstractly, adapt to unexpected situations, and gain from instruction and experience [2]. Although psychologists believe that g exists, evidence for specific intelligence (s), a measure of specific skills in restricted domains, has also been identified. Some psychologists [3]-[6] define intelligence as a combination of factors including a wide range of subject knowledge, quick thinking, and the ability to reason. Fluid intelligence and Crystallized intelligence are terms used by psychologists to describe these factors. The ability to reason and think flexibly is referred to as fluid intelligence. The term “crystallized intelligence” refers to accumulating knowledge, facts, and skills during one’s lifetime [2]. Reference [3] expanded the concept of intelligence by introducing eight different categories of intelligence: linguistic, logical/mathematical, spatial, bodily-kinesthetic, musical, interpersonal, interpersonal, and natural Intelligence. His theory challenged the traditional idea that there is only one form of intelligence, often referred to as “g” intelligence, which focuses solely on cognitive ability.

Although previous definitions of intelligence focus on humans, artificial intelligence (AI) leverages computers and machines to mimic the problem-solving and decision-making capabilities of the human mind. While several definitions of AI have surfaced over the last few decades, [8] offers the following definition “It is the science and engineering of making intelligent machines, especially intelligent computer programs.”

AI is akin to the goal of utilizing computers to comprehend human intelligence, although it does not have to be limited to physiologically observable ways [9]. The relationships between information, knowledge, and behavior are crucial in studying natural and artificial intelligence. As a result, intelligence is defined as the ability to possess knowledge by human brains and artificial systems [10].

Most AI researchers [11], [13] have made the case that intelligence includes the following features: Intelligence is a primary characteristic of an entity (or agent) that interacts with others in a particular environment and thus is able to adapt to a variety of situations. It often denotes an entity’s ability to fulfill a local goal or achieve a common objective based on a set of criteria and preferences. The interactions and engagement with other entities facilitate the entity’s individual learning,

H. El-Asfour, F. Adhnouss and K. McIsaac are with Dept. Electrical & Computer Engineering, University of Western, London, Canada (e-mail: Helasfou@uwo.ca, Fadhnous@uwo.ca, Kmcisaac@uwo.ca).

A. Wahaishi is with Soft Ware Engineering, Rochester Institute of Technology, New York, United States (e-mail: tawvse@rit.edu).

R. Aburukba is with Department of Computer Science and Engineering, American University of Sharjah, Sharjah, United Arab Emirates (e-mail: raburukba@aus.edu).

I. El-Feghia is with Faculty of Information Technology, Misurata University, Libya (e-mail: i.elfeghi@Misuratau.edu.ly).

adaptation, and flexibility that are suitable for various scenarios [13]. Any entity perceives its environment and takes action to increase its probability of achieving its objectives.

Based on this introduction, it is reasonable to conclude that intelligence recognition has been one of the most important research topics among philosophers, psychologists, and AI researchers. It is possible to recognize intelligence in its various forms, such as data, information, and knowledge, by understanding the concept of intelligence. On the other hand, the recognition of intelligence allows its modeling, which leads to the identification of forms of intelligence. One of the most important issues is how to represent intelligence so that the components and the relationships between them can be unambiguously identified in a predetermined format. However, no scientific consensus on an agreed-upon definition was reached. To understand intelligence, there must be a single definition, structure, and specific modeling for expressing how it is understood by humans and machines. Another important issue is classifying the types of environments based on their elements and the relationships between them rather than from the agent's point of view.

This paper provides an approach towards defining and developing intelligence on the basis of conceptualization. The elements of intelligence are derived from an ontological view based on the various types of environments. The forms of intelligence and their transformations between its forms are described accordingly.

This paper is structured as follows: Section II provides background and related work. Section III provides motivational intelligence views. Section IV provides intelligence: ontological view-based model. Section V provides conclusion.

II. Background and Related Work

There is no strict definition of what intelligence is. Previous researches have produced a wide range of definitions, from simple to sophisticated. All available definitions are strongly influenced by the fields interested in intelligence technology such as AI, software engineering, cognitive science, computer science, and engineering in general.

Psychologists [14] have agreed that intelligence is a key feature of human intelligence in its ability to generate novel sequences of actions, events, thoughts, and programs that bridge idealized models of the world to physical actions that affect and change the world. Intelligence can be described from a psychological perspective; it involves different mental abilities, including logic, reasoning, problem-solving, and planning.

A. Psychology Definitions

Most definitions in AI focus on the descriptive perspective of the behavior of an agent who observes the structure of the environment and performs actions based on such observation and perception. So, different definitions in various fields will be examined to derive basic components of Intelligence.

Psychologists have attempted to best conceptualize and measure intelligence for a human being. Over the last few decades, many formal and informal definitions of intelligence have been presented, but there is no scientific consensus on any single definition. When two dozen prominent psychologists were asked to describe intelligence in 1986 [15], it has been found that they all offered significantly different answers.

Psychologists [26] have questions which include how many types of intelligence there are, the role of nature versus nurture in intelligence, how intelligence is represented in the brain, and the meaning of group differences in intelligence. Nevertheless, there are two primary schools of thought that embrace different views of intelligence, its nature and its intrinsic properties. The general intelligence school of thought and the multiple intelligences school of thought are two prominent venues that derive two different theories. The advocates for the theory of multiple intelligences believe that there are different types of intelligence, while general intelligence proponents believe there is just one component from which all intelligence is formed. Every theory has a trait and pillars to support its claim [9].

Psychologists agree that a general intelligence factor, (g), relates to various mental abilities such as logic, reasoning, problem-solving, adaptation to novel situations, and how to gain from instruction, experience, and planning. Despite this consensus on the general factor of intelligence, there is a convergence of the presence of specific intelligence(s), which is a measure of specific skills in narrow domains.

While psychological definitions can vary from one theorist to the next, current conceptualizations tend to suggest that intelligence involves the level of ability to do the following; first, learn the acquisition, retention, and use of knowledge which is an essential component of intelligence [10]-[12]. Second, recognizing problems is to put knowledge to use; people must identify possible environments that need to be addressed [10], [11], [13], [15]. Third, people must solve issues by using what they have learned to develop a helpful solution to a problem they have noticed in the environment [16]. From these definitions, the conclusion can be drawn that intelligence is the mental capability that comprises the ability to reason [11], [12], to plan [12], to solve problems [14], [12], to think abstractly [14], to comprehend complex ideas [12], to learn quickly [10], [12], [17] and to adapt to new situations in life [10], [11], [16]. For a general understanding of the structure of intelligence, several theories (or models) have evolved. Theories of intelligence also serve as the foundation for attempts to measure and quantify human ability and intellectual potential, with far-reaching implications for learning, programmer design, and teamwork, among many other areas. For example, one factor/UNI factor theory: considered one of the oldest theories in the concept of intelligence that had its roots in the 18^{th} century and flourished in the 19^{th} century [18]. Based on this theory, the mind is composed of various faculties including reasoning, memory, discrimination, imagination. Energetic training can contribute to the development of these faculties, independent of each other. The theory diminishes whole abilities to a single capacity of general intelligence or "common sense". This theory is the subject of criticism by several psychologists who objected to independent faculties in the brain [15].

Spearman's two-factor theory suggests that mental capabilities are comprised of two factors of General ability and Specific abilities [19]. General ability ("G-factor"), is a universal inborn ability, considered one of the most reliable and valid measures of behavior. Specific abilities ("S-factors") are acquired from the environment and from activity to activity, which may result in differences in S-factors within the same individual [19]. Thorndike's multifactor theory, also known as anarchic theory, suggests that intelligence is not a single factor like general intelligence but a combination of multiple factors. Thorndike classified intelligence as: (1) social intelligence, (2) concrete intelligence, and (3) abstract intelligence. He further described intelligence as follows: (a) Level - the level of difficulty needed to solve a task, (b) Range - the number of tasks in a certain degree of difficulty, (c) Area - the total number of cases at every level to which the individual is capable to respond, and (d) Speed - the rapidity with which an individual can response to tasks [20].

Thurstone's theory, the primary mental abilities/group factor theory, states that Intelligent Activities are not an expression of innumerable, highly specific factors. Each of these primary factors is relatively independent of each other. There are six primary factors: (1) Number Factor (N), (2) The Verbal Factor (V), (3) Space Factor (S), (4) Memory (M), (5) Word Fluency Factor (W), and (6) Reasoning Factor (R) [21]. Guilford's model of structure of intellect projected a three-dimensional structure of intelligence. Each intellectual task can be classified based on the model of Guilford to: (1) content, (2) the mental operation involved, and (3) the product resulting from the operation [22]. In Cattell's fluid and crystallized theory, fluid intelligence is defined as the ability to solve new problems, use logic in new situations and identify patterns. In contrast, crystallized intelligence is defined as using learned knowledge and experience [23].

The two descriptions of fluid and crystallized intelligence (Gf-Gc) correspond to Catell's (1971) idea [24], which has become one of the pillars of the Cattell-Horn-Caroll theory (CHC) [25], the prevailing hypothesis of human cognitive skills. Gardener's multiple intelligence theory suggested a different view. He proposed that intelligence must satisfy eight criteria: linguistic, logical, spatial, musical, motor ability, interpersonal, intrapersonal, and naturalistic intelligence [26].

Sternberg's triarchic theory constructed three components of intelligence: analytical skills, which enables people to think abstractly and evaluate information; creativity, which gives humans the ability to innovate solutions or new notions; and practical skills "street smarts", which enables people to interact within the environment [27]. It is evident that psychologists defined intelligence as a manifestation of behavior by observing the human's abilities to do tasks. Others, including psychologists and philosophers, believe intelligence should be defined more practically. Knowing the kinds of behaviors that help humans advance in life and the skills that promote success is essential. It is evident that, the concept of intelligence has a long history in psychology and is tied to the development of psychometric tests that can be summarized as follows:

- Standardized performance tests, which require participants to identify the proper solution to cognitive problems, are used to measure intelligence (e.g., mathematical, verbal, spatial).
- The structure of intelligence is a subject of contention, with some seeing it as a general factor and others a more specific set of essentially independent abilities. On the other hand, hierarchical models recognize the presence of both general and specific factors, which makes the data more understandable.
- At the same time, there is broad consensus that intelligence is divided into two categories: fluid intelligence (Gf), or the ability to learn new things and solve novel problems (regardless of prior experience, knowledge, or education), and crystallized intelligence (GC), or the knowledge/ information that can be used to solve problems. In following section, we will apply concepts of intelligence to AI research.

B. AI Definitions

In general, when a computer simulates activities that humans associate with human brains, such as learning and problem solving, the word "AI" is used [28]. To be consistent, a term must include the nature of human intelligence as well as other possibilities. It should not be restricted to a specific collection of senses, environments, or goals, nor a specific type of hardware, such as silicon or biological neurons [8].

Turing's famous paper in 1950, in which he offered an imitation test as a sufficient condition of being intelligent [29], can be traced back to attempts to explain the notion of intelligence and debate the potential and paths to develop it in computing machinery.

Intelligence can be defined in one sentence: "an agent's ability to achieve goals in a wide range of environments", or to succeed in a wide range of environments [30]. This definition emphasizes two characteristics that are nearly universally – but not always – found in intelligence definitions: one that emphasizes task-specific skill ("achieving goals"), and the other that emphasizes universality and adaptation ("in a wide range of environments"). Others focus on how to utilize rationality to select one of the outcomes of actions. Rationality can be defined as behavior in the face of constraints on execution time and machine resources [31]. Intelligence is a complicated concept (maybe that is why many people try to avoid it or narrow it down).

Reference [32] defined intelligence as "the ability for an information processing system to adapt to its environment with insufficient knowledge and resources." An information processing system is one whose internal activities and interactions with its environment can be investigated without addressing the physical processes that carry out the activities and interactions.

To adapt means the system learns from its experiences. Insufficient knowledge and resources mean the system operates under the following constraints: i) finite, the system's information processing capacity is constant, ii) real-time, every task has a deadline connected to it, and iii) open, the knowledge and tasks that the system can accept are unrestricted if they can be represented in the interface language.

The notion of intelligence in the context of knowledge modeling is based on three principles: data, information, and knowledge [15]. The measures and symbols of the world around us are referred to as data. External signals are used to present data taken up by various sensory equipment and organs. To put it another way, data can be thought of as raw signals, facts, and figures. Data becomes information in this sense when it becomes relevant to our decision-making process. In the perceiver's mind, knowledge is the subjective interpretation of information to recognize the applications and approaches to act upon.

As a result, knowledge gives information a meaning, allowing it to inspire action. Intelligence is wisdom, which entails using awareness, insight, moral judgements, and principles to build new information and improve old knowledge [15]. Reference [33] stated that "the intelligence of a system is a measure of its skill-acquisition efficiency over a scope of tasks, concerning priors, experience, and generalization difficulty." Reference [32] argues that evaluating intelligence only by measuring ability at a given task is insufficient because skill is significantly regulated by prior knowledge and experience.

It is apparent that AI researchers described intelligence as a property owned by an entity (agent or machine) to manifest behavior by doing tasks. AI researchers claim that intelligence has the following quality attributes [7]:

- Intelligence is a primary feature of an entity or agent which supports the interaction, engagement, and the adaptation within various environments settings.
- Intelligence is a measure and an indication of an entity's ability of fulfilling a local stated goal of achieving a set of defined objectives that satisfy a set of criteria.
- Intelligence places an affirmation on learning, adaptability, and flexibility in various environments and scenarios.

III. Motivational Intelligence Views

The main motivation of the proposed model is to identify and understand the nature of intelligence as the multi forms that an entity (human or machine) can possess, rather than the ability to successfully perform behavior. Based on our observation, most definitions of intelligence identify two essential elements, which relate intelligence to the individual's inner world (knowledge) and relate intelligence to the external world of the individual (environment).

Many researchers believe that data, information, and knowledge exist in sequential order [34]. Almost all modern sciences and engineering professions rely on information and knowledge. However, data, information, and knowledge are traditionally treated differently [3]. Data are frequently a quantitative abstraction of external objects and/or relationships obtained directly from a captured state. The state can be considered raw signals, facts, and numbers like Joe, Smith, 1234 Circle, SLC, UT, 8404, and 010101.

Data that are meaningful or data that have been interpreted are referred to as information. The information or data consumed with inference is thus referred to as knowledge. In other words, information incorporated into an entity's reasoning resources and made ready for active use within a decision process is referred to as knowledge. Within this context, an environment defines the surroundings, which has a logical boundary, and is where different entities exist and coexist. However, entities rarely exist in isolation; instead, they tend to interact to varying extents with their surrounding entities. Each entity is distinguishable from other entities (distinct and independent existence).

The universe can be thought of in terms of an environment in which the existence of its "entities" is governed by a set of axioms (or rules) and coexistence with other entities. The universe can be divided into categories depending on the existence of entities, coexistence, or both. Fig. 1 depicts the relationship between the environment, the universe and space.

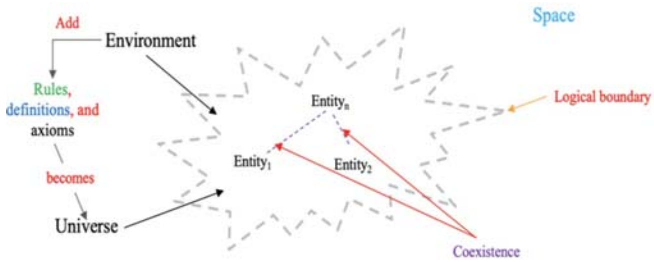


Fig. 1 Relationship between the environment, the universe and space

Based on these changes, the environment can be categorized as follows:

- Closed environment (CE): This environment can be in one or more states. Static Closed Environment (SCE) and Dynamic Closed Environment (DCE) are the two subcategories of CE. Because its elements do not change, the SCE has only one state. On the other hand, a DCE may have numerous states because only their relationships change, while the entities remain unchanged.
- Open environment (OE): Changes can occur in entities, relationships, or both in this environment. Therefore, multiple states can be captured. Fig. 2 shows the category of environments.

Additionally, Dynamic Closed Environment will be decentralized, where no single entity is the sole authority, and its entities are geographically distributed.

How an entity can develop intelligence can be conceptualized as a journey. The journey begins by capturing the state of the universe. A universe that captures another universe's state is known as (U_2-Intelligence space), whereas a universe that captures its own state is called (U_1-Reality). A state can be one or many depending on the changes that may occur in the elements of U_1, which are the relationships as illustrated in Fig. 3.

Each state describes the structure of entities that can be within the universe. The states will be abstracted without a relationship to time for simplicity. When U_2 captures the state of (U_1), it is possible to convert its state to another format that U2 can understand. This captured state is called the first form of intelligence (raw intelligence). This form alone has no significance, has not been processed, and lacks context. It can be stored as form1 in (U_2). Adding this form within the proper context will turn form1 into form2.

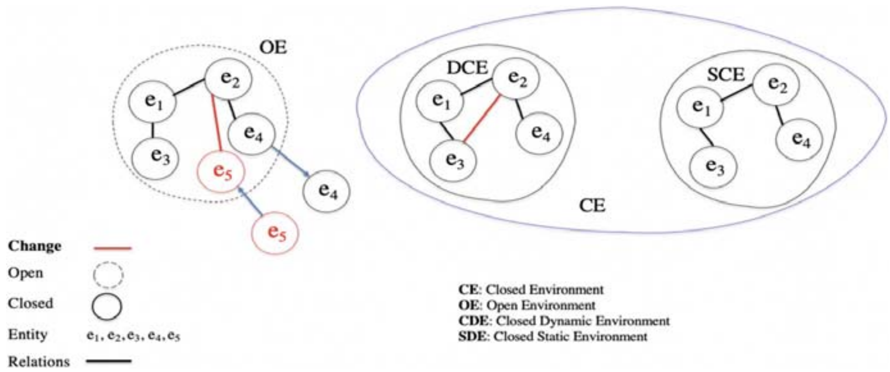


Fig. 2 Classification of the environments

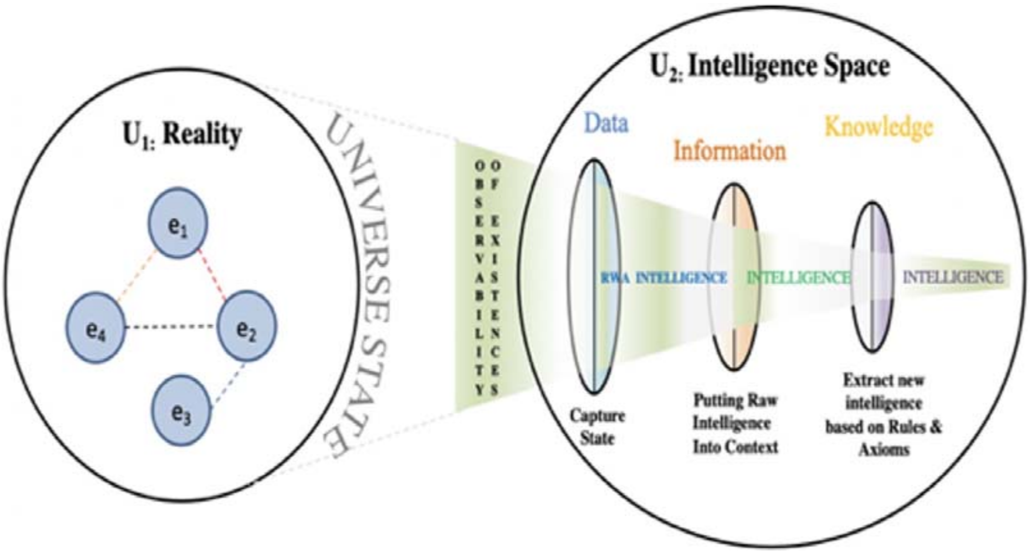


Fig. 3 The nature of intelligence

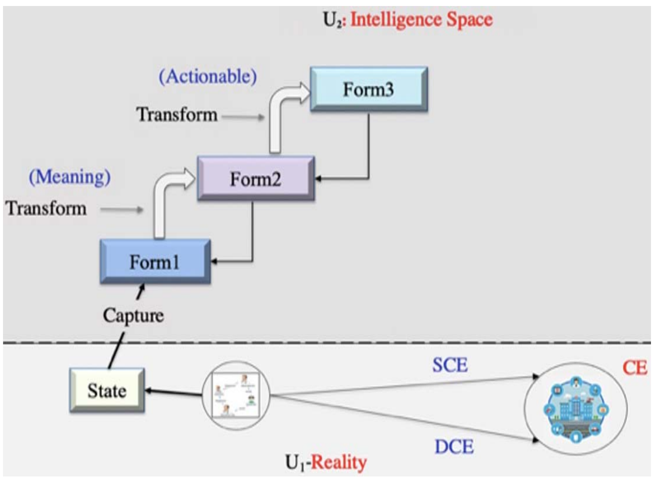


Fig. 4 Relation between the state and forms of intelligence

Each state describes the structure of entities that can be within the universe. The states will be abstracted of time for simplicity. U_2 (space intelligence) should have a conversion function that can convert the state to another format, called the first form of intelligence (raw intelligence). This form alone has no significance, has not been processed, and lacks context. It can be stored as form1 in U_2. Putting this form with proper context will turn into another meaningful form.

(U_2) may have the appropriate way to enable it to transform raw intelligence into another form (form2) that will have a structure or be present in a particular context. Form2 can be another form (form3), which is an actionable form2 available in the proper format. Fig. 4 depicts the nature of intelligence and its forms.

The following example illustrates the concept of forms of intelligence. Imagine that someone (U_1 -Reality) feels sick, and s/he goes to see a physician (U_2 Intelligence-space). U_2 observes temperature by measuring the body temperature of U_1 with a mercury thermometer. Mercury expands and contracts with temperature changes, which represents captured state. The state U_2 might be converted into another format within U_2. For example, the captured state converts into a number (39 °C scales) called raw intelligence (form1). This form alone tells U_2

nothing. U_2 can associate 39 °C with body temperature and provide context and meaning for 39 °C. As a result of this augmentation, U_2 gains a new level of intelligence known as form2. U_2 may attach a purpose to the body temperature of 39 °C to make and implement a decision by using some rules. For example, if the temperature is above 37.5 °C, then obviously U_1 has a fever. As a result, U_2 will have a new level of intelligence known as form3. It is clear from this example that U_2 can develop intelligence without being aware of its behaviors by other universes. Intelligence is a descriptive term that can have three different forms, each of which is derived from the preceding one.

In this work, we view knowledge as a form of intelligence and thus define what form will knowledge represent in intelligence in addition to the other possible forms. The work also defines what transformations will be utilized to reach achieve such forms. Consequently, we define and describe the adequate models of intelligence that are suitable for the various environments mentioned above. It is noteworthy, that we must incrementally build up the intelligence systems, to have a complete picture at each step of the way and thus to automatically ensure that the forms and their transforms are valid.

IV. Intelligence: Ontological View Based Model

This work focuses on aspects related to intelligence concerning the "state" of a "universe." A universe state can be associated with an ontological view (OV) for a conceptualization structure which is supported by language. "A conceptualization is an abstract, simplified view of the world that we wish to represent for some purpose" [35]. An ontology is a specific, formal representation of a shared conceptualization of a domain [36]. It is formal in the sense that machines can read and understand it. It is shared in the sense that the community members have agreed on its content. Based on this assumption, a model of intelligence will be given, as shown in Fig. 5, in which we will start with the idea of where existence occurs in a universe. With that being given, let us begin with conceptualization and ontology with a given language L and a set of axioms that shape the intended model, which will be the base for intelligence associated with changes that might occur in the environment.

For a Static CE with a given OV that reflects conceptualization, there is no intended model, but rather a model derived from the tuple: $C =< D,R >$ [37]. This model can be mapped or correspond directly to the existences in the universe that represent a state associated with the environment St =< G, N > where G is the domain and N denotes the relationships. In this case, the structure represents the state of a Static CE.

For the Dynamic CE, since the intended models correspond to the C =< D, W, R >, there will be multiple extensions that reflect numerous structures such as s =< D, R >, s ∈ S [37], where each structure corresponds to a possible state. Each structure is an extension associated with semantics to be counted as a model generated by the language L, which can be viewed as the base of intelligence, i.e., all models derived from (complete and sound) OV should correspond to the intended model, which in turn is considered intelligence. In this environment, the state can be represented as a structure St =< G, S, T > where S is a set of possible worlds that can be considered possible states and T is an intentional relation.

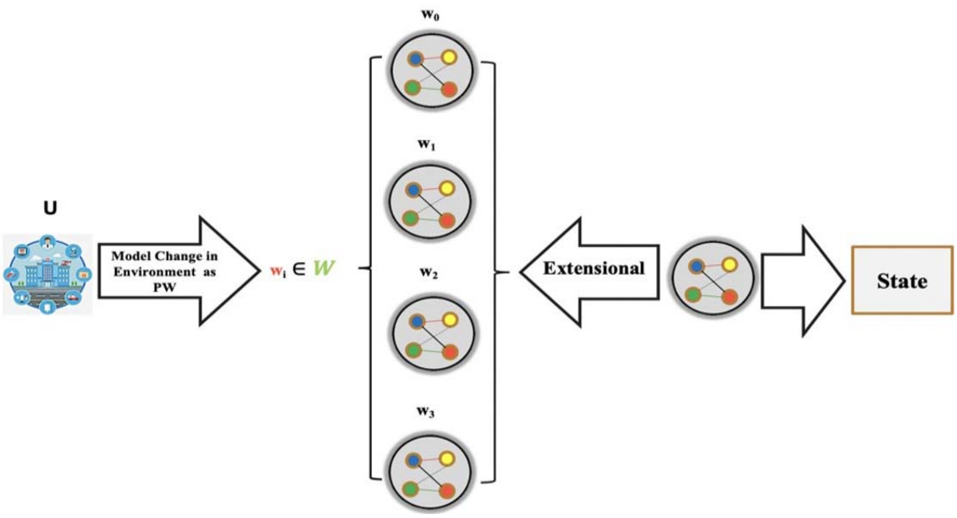


Fig. 5 Correspondence between the current state and the possible world

It will use OV to enable the universe (intelligence-space) to derive forms of intelligence. Fig. 6 shows the correlation between intelligence, conceptualization, and OV. Form2 will have meaning by adding semantics (logical language) to form1. This form should be compatible with the model generated by the OV in the conceptualization model. Also, OV will derive another form of intelligence (form3) from form2 by utilizing axioms.

A. Classification of the Environment: Possible World Based Theory

This section will propose an approach to understanding the nature of the environment in the context of changes in its elements. Based on this approach, the types of environments will be determined.

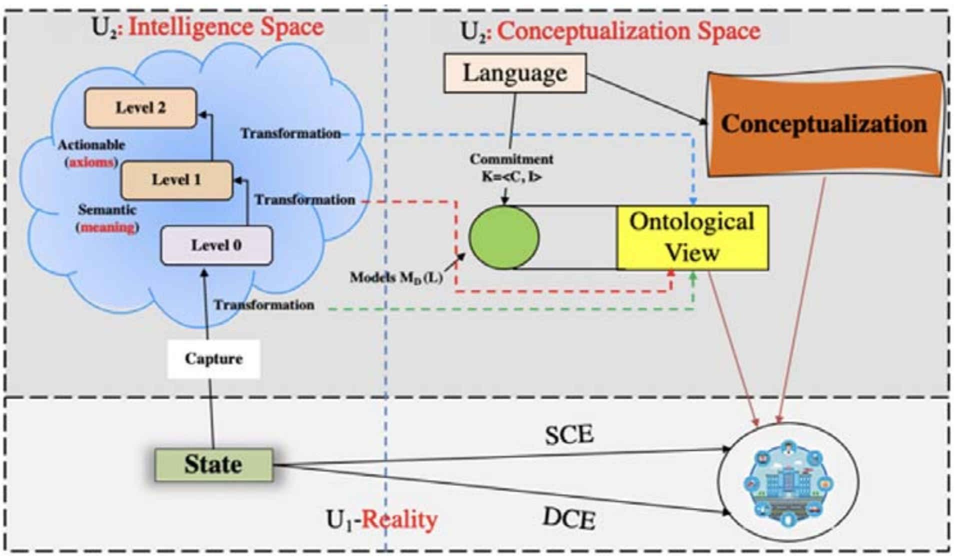
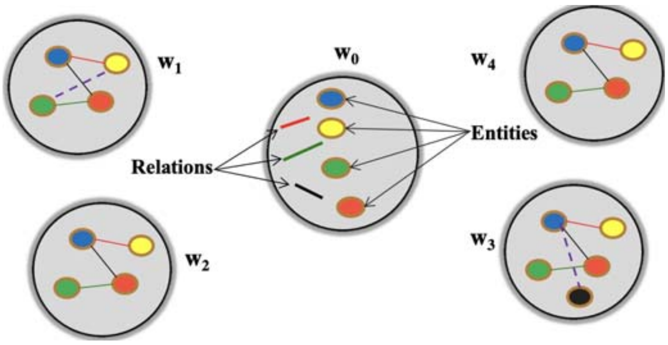
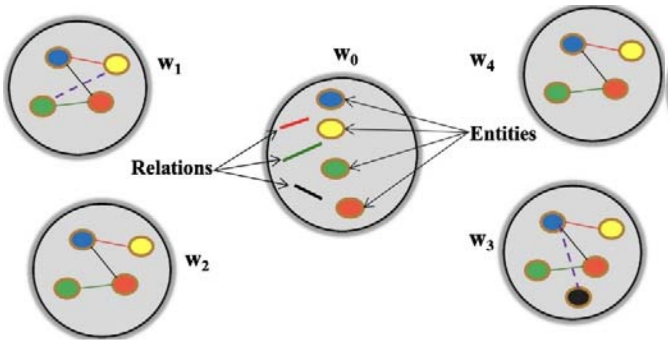


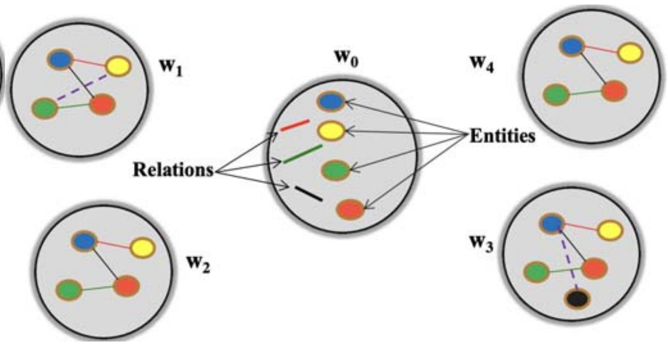
Fig. 6 Relation between conceptualization model and intelligence



(a) SCE



(b) DCE



(c) OE

Fig. 7 Types of environments

A universe can be considered as an environment governed by a group of axioms (or rules) that govern its entities, as discussed in Section III *C*. A possible world is a complete representation of how the universe could be. Possible worlds are alternative worlds, one of which is the actual world. In the information environment, the possible world is specified by the existence of entities and coexistences through relationships. Type of the environment is an essential element in Intelligence. For example, Figs. 7 (a)-(c) depict the type of universe based on changes in its elements. If W is a set of the possible worlds to universe U_1, which are W = { w_0, w_1, w_2, ..., w_n} where, $w_i \in$ W, the type of universe can be determined using the origin of W where it can be greater than or equal to one as shown below:

|W| = (= 1) *if only if all possible worlds are, identical there is not change (SCE).*
> (1) & (*different in relations) if only if there is at least one world different that is (DCE).*
(> 1) & *(different in entities) if only if there is at least one world different*

B. Intelligence: A Proposed Definition and Formulation

Before we start defining and modeling Intelligence, we need some essential principles that help us in this work. First, Intelligence is descriptive (not actionable or observable) that can lead to a specific view. Second, we should distinguish between Intelligence and intelligent. Intelligent (adjective) is characterized as an entity that possesses Intelligence while Intelligence (noun) is characterized as the nature of Intelligence which can exist as data, information, or knowledge.

We will start with our informal definition of Intelligence: "Intelligence is capturing the state of any universe in the narrow sense. In the broad sense, Intelligence does not depend only on capturing the state but also on transforming between its forms: data, information, and knowledge." There are three essential elements in this definition: Forms, transformations, and states. Clearly, the universe should capture a state and convert it to raw Intelligence, then transform it into other forms. These forms will be referred to as data, information, and knowledge in our terminology. The state represents the universe's structure, and it is either a changed or an unchanged state.

Humans can easily capture a state and use language to transform that state into other forms to build their Intelligence. In general, having a sufficient level of logical language would be a fair assumption to help the universe build Intelligence. In the context of conceptualization, the OV can provide a base for two levels of transformation of the "intelligence" forms. Firstly, it provides the associated data with two aspects of semantics:

- The association of the data (state) with the corresponding conceptualization structure.
- The association of the data with the corresponding specification using the supporting language.

Secondly, the association axioms of the OV provide the "information" form of intelligence with "actionable" transformation which supports direct "reasoning."

As we indicated in our informal definition, the first stage in building intelligence is capturing a state of the universe (Reality U_r) by another universe (intelligence-space U_{in}); U_{in} should have a function that allows it to convert this state into raw form. U_{in} can either preserve the captured state in its original format or change it to a more understandable format. This raw form of intelligence will be represented as data within U_{in}. Fig. 8 shows how U_{in} converts the captured state into data.

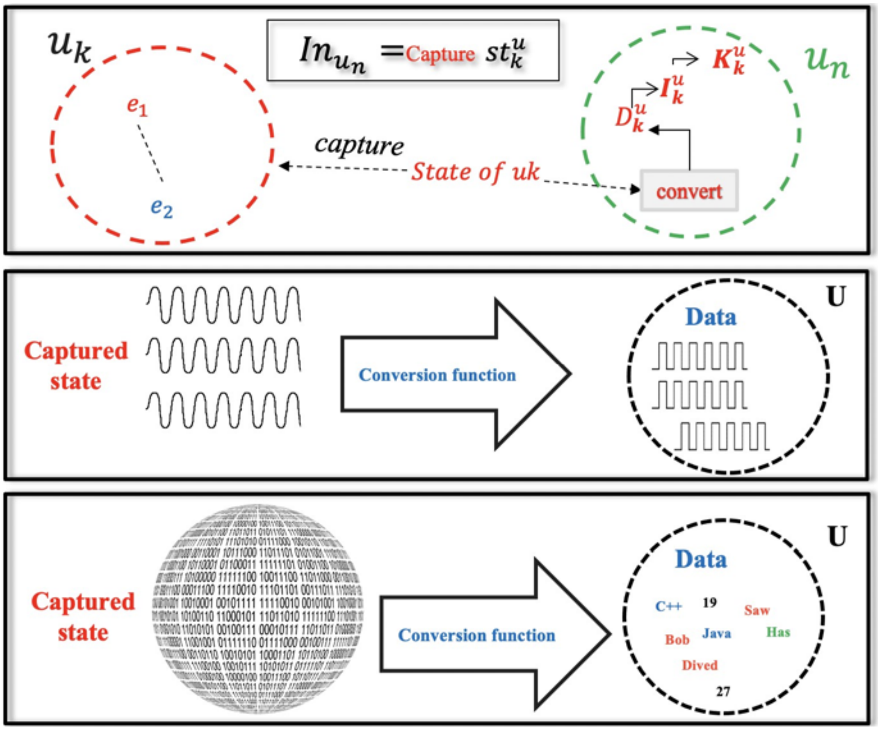


Fig. 8 How to convert the captured state into data

The conversion function can be written formally as:

$$C_f\, St_r^{U_r} = D^{U_{in}} \tag{1}$$

where St_r denotes the state of the (U_r), which is St_r=< G_r,N_r >or < G_r,S,T > and D^{Uin} represents data within the intelligence-space. However, the data are collection of meaningless text, numbers, symbols, signals, entities, and relationships captured and stored. Therefore, data are not sufficient for reasoning, and should be processed or provided context before it can be meaningful. The OV emerges to specify data in the same way as the conceptualization structure to give the data meaning. The function of transforming from data to information will be as follows:

$$T_{f1}<D^{U_{in}}, OV>= I^{U_{in}} \quad (2)$$

An OV is an ontological view that facilitates data transformation into information. This information should be compatible with the information produced from the OV in the conceptualization model.

Keep in mind that the result of the conversion function will produce a structure like the structures of the captured state which are $St_r =< G_r,N_r >$or $< G_r,S,T >$. In principle, we can define data explicitly in two ways: extensionally and intensionally. If the observable universe captures numerous states that are identical, the data are considered extensional (immutable). At the same time, it is intensional if the observable universe captures a set of states and there is at least one state different.

The formal language will be required to specify intensional and explicit data. In general, however, fixing a utilized language and constraining the interpretations of that language in an intensional approach, using appropriate axioms, is a more effective way to specify data.

In the static data, let L be an extensional logical language with V_L as its vocabulary and S as a structure, $C_L = (G_r,N_r)$. An extensional L structure or model is a tuple $M = (C_L,I)$, where I is an extensional interpretation function which is an overall function: $I : V_L \rightarrow G_r \cup N_r$ which maps each vocabulary symbol V_L to a G_r element or extensional relation belonging to the set N_r. In contrast, dynamic data require ontological commitment to extend the standard (static data) notion of "meaning" for vocabulary symbols for the intensional case. Let L be an intensional logical language with V_L as its vocabulary and C as a structure, where $C_L =< G_r,S,T >$ is an intensional relational structure. An intensional language structure or ontological commitment for L is a tuple $K = (C_L,\Im)$, where $\Im$ is an intensional interpretation function which is an overall function $\Im : V_L \rightarrow G_r \cup T$ that maps each vocabulary symbol of V_L to either an element of D or an intensional relation belonging to the set T.

The intensional meaning of a language has been specified and its models have been constrained using an ontological commitment. As a result of logical language and a specific ontological commitment, various intended models will be generated. Any model that will be generated is called an intended model of L according to K iff:

- For all constant symbols c $\in V_L$ we have $\Im$ (c) = I(c)
- There exists a world w $\in S$ such that, for each predicate symbol v $\in V_L$ there exists an intensional relation $\rho \in T$ such that $\Im$(v) = ρ and I(v) = ρ (w).

The role of the OV is most clearly illustrated by the idea of intentional models that makes OV a theory designed to explain the intended meaning of the vocabulary used by a logical language.

Based on the OV axioms, OV provides the "information" form of intelligence with an "actionable" transformation that supports direct "reasoning". An OV can be built consisting of a set of logical formulae. For instance, OV for Logical language L and $A_1,A_2,...,A_n$ is a set of axioms that will specify our domain with increasing precision. Each axiom will contain a set of rules $(r_1,r_2,...,r_n)$ where $A_1 = \{r_1,r_2\}$, $A_2 = A_1 \cup \{r_3\}$ and $A_3 = A_2 \cup \{r_4,r_5\}$. The reasoning can be built based on these axioms to infer a new form of intelligence called knowledge. This form of intelligence can be denoted as:

$$T_{f2}< I^{U_{in}}, OV >= >= K^{U_{in}} \quad (3)$$

where I is information, and actionable are derived from axioms in OV. From (1)-(3), three forms of intelligence have been described.

V. Conclusion

Different definitions of intelligence, as well as theories of intelligence, were addressed. Although intelligence has been defined as observable behavior, it can also be characterized as descriptive intelligence. Intelligence has been defined as descriptive and modeled based on conceptualization modeling in this work. In our intelligence model, we considered the different types of closed environments in which the environments have been categorized based on their states. These states are static or dynamic closed. Each form of intelligence (data, information, and knowledge) has derived from an OV.

References

[1] R. J. Sternberg, "Contemporary theories of intelligence." 2013.
[2] M. Ziegler, E. Danay, M. Heene, J. Asendorpf, and M. Buhner, "Openness, fluid intelligence, and crystallized intelligence: Toward an integrative model matthias ziegler1, erik danay1, moritz heene2, jens asendorpf1, markus buhner3 humboldt-universit¨ at zu Berlin, Germany 2 karl franzen universitat graz, austria," 2012.
[3] J. K. Debenham, *Knowledge systems design*. Prentice-Hall, Inc., 1989.
[4] J. McCarthy, "What is artificial intelligence," *URL: http://www-formal. stanford. edu/jmc/whatisai. html*, 2004.
[5] G. Yilam and D. Kumar, "Machine learning prediction of human activity recognition," *Ethiopian Journal of Sciences and Sustainable Development*, vol. 5, no. 1, pp. 20–33, 2018.
[6] Y. Wang, "On abstract intelligence: Toward a unifying theory of natural, artificial, machinable, and computational intelligence," *International Journal of Software Science and Computational Intelligence (IJSSCI)*, vol. 1, no. 1, pp. 1–17, 2009.
[7] F. Daniel, "What is artificial intelligence? an informed definition," http://https://emerj.com/ai-glossary-terms/what-is-artificial-intelligencean-informed-definition/, 2018.
[8] R. J. Sternberg, "The concept of intelligence and its role in lifelong learning and success." *American psychologist*, vol. 52, no. 10, p. 1030, 1997.
[9] K. Desiree, "Two theories on the nature of intelligence," http:/https://www.studymode.com/essays/Two-Theories-On-The-NatureOf-1417968.html, 2013.
[10] R. J. Sternberg, *Handbook of intelligence*. Cambridge University Press, 2000.
[11] S. Ceci, D. Halpern, J. Loehlin, R. Perloff, and R. Sternberg, "U. neisser, g. boodoo, tj bouchard jr., aw boykin, n. brody," *Artificial Intelligence: Critical Concepts*, vol. 4, p. 109, 2000.
[12] L. S. Gottfredson, "Mainstream science on intelligence: An editorial with 52 signatories, history, and bibliography," pp. 13–23, 1997.
[13] A. Binet and T. Simon, "Methodes nouvelles pour le diagnostic du´ niveau intellectuel des anormaux," *L'annee Psychologique´*, vol. 11, no. 1, pp. 191–244, 1904.

[14] W. V. Bingham, "Aptitudes and aptitude testing." 1937.
[15] D. Wechsler, "The measurement and appraisal of adult intelligence," 1958.
[16] S. Legg and M. Hutter, "Intelligence: Many definitions," 2006.
[17] J. Drever, "A dictionary of psychology." 1952.
[18] R. J. Sternberg, "Theories of intelligence." 2018.
[19] J. Buckley, *Investigating the role of spatial ability as a factor of human intelligence in technology education: towards a casual theory of the relationship between spatial ability and STEM education.* KTH Royal Institute of Technology., 2018.
[20] R. M. Thorndike, G. K. Cunningham, R. L. Thorndike, and E. P. Hagen, *Measurement and evaluation in psychology and education*. Macmillan Publishing Co, Inc, 1991.
[21] L. L. Thurstone, "A method of scaling psychological and educational tests." *Journal of educational psychology*, vol. 16, no. 7, p. 433, 1925.
[22] J. P. Guilford, "Some changes in the structure-of-intellect model," *Educational and Psychological Measurement*, vol. 48, no. 1, pp. 1–4, 1988.
[23] R. B. Cattell, "Theory of fluid and crystallized intelligence: A critical experiment." *Journal of educational psychology*, vol. 54, no. 1, p. 1, 1963.
[24] "Abilities: Their structure, growth, and action." 1971.
[25] K. S. McGrew, "The cattell-horn-carroll theory of cognitive abilities: Past, present, and future." 2005.
[26] H. Gardner, "Multiple intelligences," *New York.-1993*, 2010.
[27] R. J. Sternberg, "Toward a triarchic theory of human intelligence," *Behavioral and Brain Sciences*, vol. 7, no. 2, pp. 269–287, 1984.
[28] N. Gupta, "A literature survey on artificial intelligence," *International Journal Of Engineering Research & Technology (IJERT) ICPCN*, vol. 5, no. 19, 2017.
[29] A. M. Turing and J. Haugeland, "Computing machinery and intelligence," *The Turing Test: Verbal Behavior as the Hallmark of Intelligence*, pp. 29–56, 1950.
[30] S. Legg, M. Hutter *et al.*, "A collection of definitions of intelligence," *Frontiers in Artificial Intelligence and applications*, vol. 157, p. 17, 2007.
[31] S. Russell, "Rationality and intelligence," in *Foundations of rational agency*. Springer, 1999, pp. 11–33.
[32] P. Wang, "On the working definition of intelligence," Citeseer, Tech. Rep., 1995.
[33] F. Chollet, "On the measure of intelligence," *arXiv preprint arXiv:1911.01547*, 2019.
[34] C. Zins, "Conceptual approaches for defining data, information, and knowledge," *Journal of the American society for information science and technology*, vol. 58, no. 4, pp. 479–493, 2007.
[35] M. R. Genesereth and N. J. Nilsson, *Logical foundations of artificial intelligence*. Morgan Kaufmann, 2012.
[36] R. Studer, V. R. Benjamins, and D. Fensel, "Knowledge engineering: principles and methods," *Data & knowledge engineering*, vol. 25, no. 1-2, pp. 161–197, 1998.
[37] N. Guarino, D. Oberle, and S. Staab, "What is an ontology?" in *Handbook on ontologies*. Springer, 2009, pp. 1–17.