On Measuring the Intelligence Level of Knowledge Representation and Processing Systems[1]

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Abstract

This paper uses the models DIKW and DIKW to evaluate the intelligence level of knowledge representation and processing systems.

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ACM Classification: H1, I2

1. ***Basic models***

In order to formally evaluate the knowledge representation and processing (KRP) models, one first need to clarify certain terms such as: data, knowledge and information. Several definitions of these terms are available and accepted as suitable for applications. Still, there are subtle differences between them. Kurfess (1999), follows the chain of "data → knowledge → information" and explains the differences using the definitions in the literature [5]. Data is the basic part of any representation of knowledge. Because chronologically, the word "information" appeared first, several definitions describe the data through the information word. The DIKW model follows the "Data → Information → Knowledge → Wisdom" chain [11]. Thus, information is defined from data, knowledge is defined from information, and deep understanding is based on knowledge. Bellow are the basic data and definitions according to the most relevant literature.

Data – first known use: 1646.
Information – first known use: 14th century.
Knowledge – first known use: 14th century.

Definition D.1 (MWD [15] / data:)

1. factual information used in judgments, discussions or calculations;
2. information produced by a device or organ;
3. information in numeric format that can be transmitted or processed.

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Definition I.1 (MWD [15] / information:)

1. knowledge obtained through research, study, instruction;
2. communicating or receiving knowledge;
3. a signal or character transmitted / received (by communication systems or computers), part of a message.

Definition K.1 (MWD [15] / knowledge:)

1. everything that is known through acquisition or association;
2. what is obtained by deduction / reasoning;
3. the totality of truths, information and principles highlighted by the human mind.

Definition D.2 (EOD [16] / data:)

1. facts and statistics collected to be stored or analyzed;
2. quantities, characters or symbols processed by a computer that can be stored or transmitted in the form of electrical signals and can be stored using magnetic, optical or mechanical environments.

Definition I.2 (EOD [16] / information:)

1. facts available or learned about something or someone;
2. data processed, stored or transmitted by a computer.

Definition K.2 (EOD [16] / knowledge:)

1. facts, information or skills gained through experience or education;
2. what is known.

Definition D.3 (DIKW [11] / data:)

1. facts, signals or symbols, unorganized and unprocessed, which have no meaning or value in the absence of context and interpretation;
2. entities without use before interpretation.

Definition I.3 (DIKW [11] / information:)

1. data having meaning and purpose;
2. useful data to answer questions such as: who, what, when, where, how many etc.;
3. what is deduced from the data and useful to the decision-making process or actions.

Definition K.3 (DIKW [11] / knowledge:)

1. processed, structured, organized information to be useful to the action;
2. knowledge is obtained from information, as information is obtained from data;
3. knowledge is gained through learning, thinking and understanding of the context of the problem.

Definition D.4 (Liew [7] / data:) ”Data consist of recorded symbols and signal readings, where

- data consist of recorded ”symbols” and signal readings, where
- symbols consist of elements considered as the building blocks of communication: words (text and/or verbal), numbers, diagrams, and images (still &/or video), and

- signals include sensor and/or sensory readings of light, sound, smell, taste, and touch."

Definition I.4 (Liew [7] / information:) "Information is a message that contains relevant meaning, implication, or input for decision and/or action.
- Information comes from many sources: current (communication) and historical (processed data or 'reconstructed picture') sources.
- The purpose of information is to aid in making decisions and/or solving problems or realizing an opportunity."

Definition K.4 (Liew [7] / knowledge:) "Knowledge is the
1. cognition or recognition (know-what);
2. capacity to act (know-how);
3. understanding (know-why)

that resides or is contained within the mind or in the brain. The purpose of knowledge is to better our lives."

Knowledge can be informal or tacit (implicit) or formal (explicit). Implied knowledge exists in the mind of man, and is difficult to formalize, communicate, copy or steal; it is the result of individual experience, action and revelation. Existing knowledge exists independently of the individual, can be formalized, distributed, copied, processed, stored, easy to steal, and is the result of applying principles, procedures and processes to concepts. According to Ramirez and Valdes [10], knowledge definitions complement one another and some are more practical. A Hobbes' definition [4], which highlights the four necessary properties of knowledge: the integration of concepts, the identification by names of concepts, the use of names in the creation of sentences, the validation of sentences. These considerations are an important motivation in using formal logic in representing knowledge. Other definitions call for the existence of associations between concepts, as in the model, inspired by Vygotsky [14], and called semantic networks. Taking into account the various disciplines that have tried to define knowledge such as: Psychology, Knowledge Science, Philosophy, Linguistics, Systems Analysis and Artificial Intelligence, Ramirez and Valdes have identified the common elements of existing theories as follows:

- Knowledge is composed of elementary pieces, called concepts.
- The concepts are in relationships with each other.
- Concepts and associations are parts of structures whose dynamics stabilize over time.

From this perspective, the knowledge can be factual (by describing the attributes of the concepts), respectively procedural (by describing the evolution of the structures). More specifically, declarative knowledge describes what is known about the problem we need to solve, while procedural knowledge shows us the steps to get the solution. Both declarative and procedural knowledge may be specific to the problem area or are based on elements of common knowledge specific to the human being. Procedures specific to the procedural approach include those of a heuristic nature. Also, in some contexts, meta-heuristics or meta-knowledge, i.e. a higher-level knowledge that allows experts to choose from problem-solving strategies on the most efficient one, can be talked about. Ackoff [1] has added a new interpretation toward DIKW model based on a connectedness-understanding view. Understanding relations makes possible the transformation from data to information, while understanding the patterns will produce knowledge. Moreover, by understanding the principles, a new level is obtained: wisdom. Mainly, "wisdom is an abstraction of knowledge, which is itself an abstraction of information, which is itself an abstraction of data", according to Swetnam et al [13], when discussing the levels of intelligence of a system.

2. *Intelligent systems*

Liew [7] has introduced an extension of the DIKW model due to some circular definitions of the basic notions: data, information, knowledge. The new level, called intelligence, follows knowledge and is suitable to achieve wisdom. In the following, the main interest will be the computational intelligence (CI). However, firtsly the terminology related to intelligence is considered.

Definition CI.1 (Liew [7] / intelligence:) "Intelligence is thought or mental processing capacities:

1. *learning* – pattern matching, memorizing, recalling, correcting mistakes, sense-making;
2. *conceptualizing* – modelling, prioritizing, categorizing;
3. *analytical thinking* – analyzing, interpretation, understanding, scenario playing, evaluating;
4. *critical thinking* – logic, reasoning;
5. *creative thinking* – imaging, imagining, supposing, hypothesizing, simulating;
6. *quick thinking;*
7. *performing* – reading, speaking, music, physical activities etc.;
8. *problem solving, decision making, judging;*
9. *affective thinking* – emotion handling.

According to [7], the wisdom can be seen as: *the most desired virtue, a high spiritual state, a philosophy* (based on critical reflection and sound judgment), *an expert system* (in association with the fundamental pragmatics of life where four conditions support the development of wisdom: acquisition, generation, development, mastering critical life experiments), *learning* (from experience, by practical theorizing, meta-learning), *interactive minds* (through external dialogue or internal/virtual dialogue), and *critical reflection* (paradigmatic, prescriptive, and causal).

Following Engerbrecht [3], "intelligence as the ability to comprehend, to understand and profit from experience, to interpret intelligence, having the capacity for thought and reason (especially to a high degree)", when seaching dictionaries. The mentioned author identifies five paradigms of computational intelligene: artificial neural networks (NN), evolutionary computation (EC), swarm intelligence (SI), artificial immune systems (AIS), and fuzzy systems (FS). Recently, new developments appeared like intuitionistic-fuzzy systems, and neutrosophic systems [8]. However, computational intelligence reflects on methodologies inspired from nature or try to simulate the human thinking schemes.

Legg [6] identifies 18 collective definitions of artificial intelligence, 35 psychologist definitions, and 18 AI researcher definitions. This is to show how complex is to define artificial intelligence and consider to integrate it in specific applications. A short selection, of definitions, suitable to intelligent KRP systems, follows:

Definition CI.2 (cited by Legg [6] / intelligence:)

1. "Intelligence is the power to rapidly find an adequate solution in what appears a priori (to observers) to be an immense search space" by Lenat and Feigenbaum (1991).
2. "Intelligence is the ability for an information processing system to adapt to its environment with insufficient knowledge and resources" by Wang (1995).
3. "Intelligence is the ability to process information properly in a complex environment. The criteria of properness are not predefined and hence not available beforehand. They are acquired as a result of the information processing" by Nakashima (1999).
4. Intelligence is "the capacity to acquire and apply knowledge", The American Heritage Dictionary, fourth edition, 2000

Sandberg and Bostrom [12] define "a human-level machine intelligence to be one that can substitute for humans in virtually all cognitive tasks, including those requiring scientific creativity, common sense, or social skills." Even difficult to evaluate this definition, an increased interest can be seen in many fields of application [9]. Many researchers consider machine intelligence (MI) equivalent to artificial intelligence (AI). We consider that MI depends on the hardware platform, while AI, is a general approach, which is platform independent. Any MI uses AI methodologies to solve a specific problem.

In the following, the DIKIW model [7] is shortly analysed. Firstly, the dimensions of intelligence are presented: practical problem-solving, verbal ability, intellectual balance and integration, goal orientation and attainment, contextual intelligence, and fluid thought. The DIKIW model integrates "Intelligence" between "Knowledge" and "Wisdom". Efe, in [2], mentioned two categories of knowledge, and two categories of wisdom: *decision maker oriented knowledge* – "understanding the risk description and its impact on organizational goals and objectives", *analyst oriented knowledge* – "understanding how to do the risk assessment and understanding the risk description in order to set the best control activities to manage risk", *decision maker oriented wisdom* –"the ability to use the results of the analysis in the right way", and *analyst oriented wisdom* – "the ability to present the results of the analysis in the right way".

Following the basic structure of any KRP system, it is clear that 1) facts are derivation rules without premises, 2) data are derivation rules without premises, and 3) is possible to assume that any data is rule at least in one case. Hence, the DIKIW model can be applied to intelligent KRP systems.

3. ***Assessing the levels of KRP systems intelligence***

Since several systems of knowledge representation can be developed, it is questionable to assess the quality of the KRP-specific systems. In order to asses the level of intelligence, of any system including KRP systems, a review on the system operation capability is conducted.

A methodological approach was given by Swetnam et al [13], and can be resumed by the following rules.

Rule 1. A system is able to operate at the D (data) level if at least 90 points will be collected when asking for: supporting inputs as measurements data (20p), is able to store the inputs in a pool (20p), is possible to append or review the stored data (20p), support the usage of data sequences (20p), and offer database capabilities to the pool of stored data.

Rule 2. The operability on I (Information based) level, is assured if more than 80p is obtained when asking for/if: supporting queries (25p), solving queries by accessing multiple elements of the database (25p), is able to provide a trend line (10p), supporting statistical operations to provide information (10p), is able to correlate data or find correlations among the pieces of data, predicting data through state interpolation (10p), is able to combine data from more than one database (10p).

Rule 3. The system works at least at K (knowledge driven) level, if the score is greater than 80p when is evaluated for/if: ingesting or building information (20p), is able to build a model according to the received information (20p), include a model of causality making easy to understand the behaviour of the system when receive some inputs (10p), providing useful predictions about the modelled system (10p), include a set of values corresponding to a state of the modelled system (10p), is capable of self-explaining (10p), permit the prediction by extrapolation (10p), is able to estimate the system structure by unobservable elements (5p), is able to build models about different systems (5p).

Rule 4. A system is working at W (wisdom based) level if it scores greater than 80p when reviewing the following aspects: is able to ingest multiple models of a compound system (20p), support meta-modelling (20p), support what-if experimentation by changing the input models (10p), optimize the meta-model according to some metric applied to the produced information (10p), is able to provide information of improving the behaviour towards better states, according to a specific metric (10p) , self improving, support the parameter updating to fulfill the predicted better state (10p).

Moreover, the above assessment procedure is able to evaluate the systems for the following properties:

1. *representativeness* – the ability to allow the representation of the thesaurus of knowledge specific to the field and necessary to solve the problem;
2. *deductibility* – the ability to allow the evolution of structures (obtaining new structures starting from the existing ones);
3. *efficiency* – the ability to choose the most appropriate evolutionary / deductive mechanism to achieve the least effort solution;
4. *self-learning* – the ability to produce new knowledge through automated methods whenever possible.

4. ***Conclusions***

In order to evaluate the level of intelligence of decision aided systems based on knowledge representation and processing is necessary to establish clear definitions of concepts, goals, and processes. This paper reviews the DIKW model and its extensions incorporating intelligent behaviour. Finally, the rules to categorize a system according to its level of intelligence are presented. The methodology can be extended to cover specific expert systems, like big data oriented, or distributed KRP type.

References

1. Ackoff R. L., *From Data to Wisdom*, "Journal of Applies Systems Analysis", Volume 16, 1989, pp. 3-9.
2. Efe A., *Unearthing and Enhancing Intelligence and Wisdom Within the COBIT 5 Governance of Information Model*, COBIT, 2016.
3. Engelbrecht A.P., *Computational Intelligence. An Introduction*, John Wiley & Sons Ltd, 2007 (2nd ed.)
4. Hobbes T., *Elements of Law*, Natural and Political, Routledge, 1969.
5. Kurfess Franz J., *Neural Networks and Structured Knowledge: Knowledge Representation and Reasoning*, "Applied Intelligence" 11, 1 (July 1999), pp. 5-13, DOI=http://dx.doi.org/10.1023/a:1008327412259.
6. Legg Sh., *Machine Super Intelligence*, PhD Thesis, Faculty of Informatics of the University of Lugano, 2008.
7. Liew A., *DIKIW: Data, Information, Knowledge, Intelligence, Wisdom and their Interrelationships*, "Business Management Dynamics" 2(10), 2013, pp.49-62.
8. Mohammed Saeed A. A., *Recent Approaches in Knowledge Representation*, "Analele univ. Spiru Haret, Seria Matematica-Informatica", 12(1), 2016, pp. 5-12.
9. Mulgan G., *A Machine Intelligence Commission for the UK: How to Grow Informed Public Trust and Maximise the Positive Impact of Smart Machines*, NESTA, 2016.

10. Ramirez C., Valdes B., *A General Knowledge Representation Model of Concepts*, Ch3 in Ramirez, C. Ed., Advances in knowledge representation (2012), InTech, http://cdn.intechopen.com/pdfs/36656/InTech-A_general_knowledge_representation_model_of_concepts.pdf.
11. Rowley, Jennifer, *The Wisdom Hierarchy: Representations of the DIKW Hierarchy*, "Journal of Information and Communication Science" 33, 2 (2007), pp. 163180, doi:10.1177/0165551506070706
12. Sandberg A., Bostrom N., *Machine Intelligence Survey*, Technical Report #2011-1, Future of Humanity Institute, Oxford University, pp. 1-12, 2011.
13. Swetnam M., Hummel R., Mueller C., Syers P., *Intelligence Complexity*, Potomac Institute for Policy Studies, 2016.
14. Vygotsky L., *Thought and Language*, MIT Press, 1986.
15. ***, Merriam-Webster Dictionary (MWD): http://www.merriam-webster.com/dictionary/data
16. ***, English Oxford Dictionaries (EOD): https://en.oxforddictionaries.com/definition/data