Cognitive Information Systems and Related Architecture Issues

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Abstract: The rapid developments in information technology and business, must drive the progress of Cognitive Information Systems (CIS). There are some studies on the generic model of CIS analysis and design. The work herein, seeks to combine multiple CIS and Understanding-based management systems concepts into a single design strategy (UBMSS). But they weren't identified as modeling artifacts or as building blocks as enabler that are required to construct a consistent and integrated system. The artifacts that are the basis to generate functions for CIS are as follows: semi-structured documents, models of business processes, components of knowledge management, building blocks of the enterprise, and information architecture, along with autonomous software components, and methods of Artificial Intelligence (AI). The above-described parts, were merged into a single framework for CIS modeling. This framework is based on the object-oriented paradigm. The study seeks to characterize and propose an overall model that helps us comprehend CIS and UBMSS features, allowing us to build a realistic development strategy for Cognitive Information and Cognitive Management Systems (CMSs).

Keywords: Cognitive Infocommunicaton; Cognitive Information Systems; Cognitive Architecture; Cognitive Resonance; Cognitive Management Systems

1 Introduction

Within the last several decades, there has been a significant increase in the usage of information technology by various businesses. The layers and features of an Information Systems (IS) architecture are planned, designed and maintained via architecture governance. An IS architecture encompasses all components of a system by defining distinct views; numerous models materialize these viewpoints, which are articulated in diverse approaches for information systems analysis and design [1]. Baranyi et al. founded the scientific field of Cognitive Info-communications (CogInfoCom) [1, 2, 3], this scientific method has highlighted several facets of IS, as well as human-computer interactions, and offers a fresh take on IS. This notion may be thought of as a fusion of Information Systems and

Cognitive Science. The thesis is of the Cognitive Info-communication that successful CogInfoCom will improve human performance.

CogInfoCom has a tremendous influence on our world; we realize new benefits and obstacles, and scientists evaluate and study both sides on a regular basis, namely the human and machine sides. Recent studies have attempted to incorporate "emotion transplantation" into speech, improving the expressiveness of text-to-speech synthesis, training neural networks [4], and studies improving decision accuracy of ensemble-based systems to improve medical image processing, thus supporting medical diagnosis [5]. A new approach is being presented that uses a neural network without the use of a dictionary of proper nouns to anticipate secret phrases and convert them to meaningless terms in order to discover the best answer while taking into account the crucial worry about privacy [6, 7].

Using the most up-to-date methodology for modeling, evaluating, and building information systems allows for the use of architectural and system design strategies. This strategy brings together system development approaches and cognitive science theories [1]. Zachman [8] and the TOGAF methods [9] describe how we see the architecture of information systems within businesses. The evolution of technology in the field of information systems may be captured by the concepts of Data Science and semantics. The paper focuses on modern Data Science algorithms and elaborates on a solution that would be manifested in a prediction module that aids in financial decision-making using Cognitive technology the authors in Molnár et al [10], taking into account the various technological and software architectural solutions to elaborate.

The present study develops a CIS modeling framework that takes into account a variety of technical and architectural aspects and solutions.

2 Difference between Systems

Three key principles, according to Hurwitz, are: contextual understanding from the model, hypothesis generation (suggested explanations for phenomena), and continual learning from data over time [11]. As a result, Ogiela compiled a list of applications of informatics and information technology that use cognitive information processing methods [12]. So, ideal CISs are: contextual insight from the model, development of hypotheses (suggested explanations for observations) [13], and ongoing learning from information. As a result of the synergy between silicon (computer) and carbon (human) agents, the human side, benefits from improved cognition. Assists in automated data comprehension and extracts semantic information. During cognitive resonance, semantic information promotes comprehending interpretation [14]. Cognitive resonance is a beneficial synergy.

The HCI (Human-Computer Interaction) synergy incorporates and encompasses CogInfoCom as a channel and carrier. The CogInfoCom guarantees that the data stream is interpreted as a stimulus by the sensor or sensory organ in the human body. The stimulus is either row data or other forms of information that are exchanged between the persons involved in HCI. Cognitive resonance helps to extract and comprehend sensory input. Ecological psychologist Vincente Raja created principles of dynamic system theory (DST) to explain agent-environment interactions [15]. Cognitive Resonance is one of the attempts to make sense of modeling exercises in the modern data analytics environment using Data Science techniques. To move towards the age of cognitive systems, Lemieux argues that we must address how we will account for choices made by intelligent computers, including people interacting with intelligent machines [16, 17].

CISs cannot be equated to human cognition in the traditional sense due to the complexity of human cognition, as these functions are the cognitive, information processing, and reasoning activities through which humans perceive, comprehend, and apply acquired knowledge. Humans attempt to adapt to situations that may happen at any time and in any aspect of life. Typically, CIS possess domain-specific abilities. Nevertheless, a comparison between human cognition and CISs suggests a need for improvement; thus, CISs must be provided with infocommunication and the incorporation of cognitive architecture features in order to diminish the significance of domain specificity.

The information architecture that enables the creation of a framework to describe the information exchange between the carbon and silicon agents buttresses the notion that CIS may be anchored in Enterprise Architecture and LIDA [18, 19, 20, 8]. The benefit of the LIDA model is that it is an architecture that focuses of both conceptual and computational levels on cognitive processes and their structure [21].

3. Cognitivity of Zachman Framework

Zachman's paradigm characterizes the multiple views of Enterprise Systems as the distinct perspectives of business players. The viewpoints highlight the architecture's layers. The elements encapsulate the numerous models portrayed by diverse ways. By including cognitive components into the Zachman framework [8] the framework will support cognitive architecture as well.

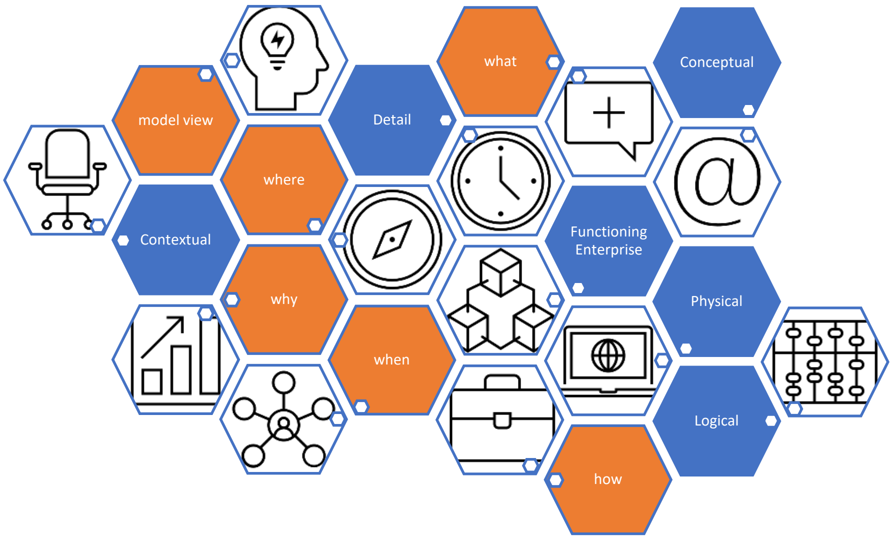


Figure 1
An abstract semantically mapping between Zachman architecture and CIS's components

The concept of CIS is to create a computer system that is integrated into the business and organizational environment. This must be accomplished via Web technologies [22, 23].

Figure 2
Cognitive elements

The scores in Figure 1 were generated based on the scale in Figure 2, using the cognitive elements as results. As a result, the model and design methodology must take into account the socio-technical environment, the Web, and software engineering approaches for enhancing and amending the system's functionality with modern data analytical solutions. On an aspect level, to satisfy the CIS requirements for cognitive resonance, where cognitive resonance is to be integrated into the two aspects that ensure the continuous improvement of the information system's cognitive level. According to the authors of Molnár et al. article [22], Enterprise IT Architecture is a collection of strategic and architectural disciplines that includes

Information, Business System, and Technical Architectures [10]. Business (systems) architecture - Specifies the structure and content (information and function) of the organization's business systems [10].

4 CogInfoCom and Cognitive Information Systems

The framework presents a model in which the human, carbon agent capabilities is captured in a cognitive model, the silicon agent services are captured in a computational model, and then a mutual map is constructed using the cognitive architecture. The objective is to establish a link between the human side and the computational architecture's model parts. The objective is twofold: one is to enable a data or business analyst to define models more effectively than would be possible otherwise, and the other is to create a model that is close to the decision-cognitive maker's capabilities; additionally, this model can be communicated to the carbon agent via some form of information communication (InfoCom). The suggested approach decomposes the data analytics paradigm into manageable components. The technique is based on collaboration across disciplines such as machine learning, information theory, ontology engineering, and computational finance. The recommended technique is a generic approach that may be used to any other area of problem-solving provided that a sufficiently specific description of the domain can be studied inside the proposed framework. A conceptual framework aids in comprehending and organizing the different components and relationships of a given system or phenomenon. A conceptual framework is crucial for understanding the actors and their characteristics, as well as their interactions and dependencies, within the context of a CIS. This framework supports the comprehensive understanding of the CIS and aids in the identification of potential improvement or optimization opportunities. In addition, it can promote the integration of interdisciplinary perspectives, in CIS as in BENIP (Built ENvironment Information Platform) [24], emergency evacuation through FDS+EVAC (Fire Dynamics Simulator with Evacuation) [25], climate protection evaluation method [26], etc., where all contributing to the success of info-communication meanwhile, emphasize the need of it.

5 Cognitive Mapping of CogInfoCom

The Repertory Grid [27] is one way of cognitive mapping. The Repertory Grid (RG) approach has several applications. This technique's findings may be used to analyze decision choices or design training programs for interpreting MIS data, while it can also reveal mutual understanding across diverse roles and responsibilities within a company. The RG can generate cognitive maps that show the junction of mutually agreed and portrayed information, and proved bits of knowledge. The decision-makers cognitive capacities are important variables in a business process because they arbitrate between easily accessible information and the decision's consequences. 1 Three common cognitive mapping strategies are: Causation, semantics, and idea mapping (see [28]). In this way, distinct management groups might be exposed to the cognitive structures and belief systems that they employ to interpret difficulties. Cognitive resonance is a key notion in interpreting the output of a computer process. Complex information streams resulted from current IT developments. Computational intelligence and machine learning produce the stream of data. The cognitive resonance may assist analyze and distinguish between the carbon and silicon agents' conceptions. The information stream comprises processed data, an explanation of the findings based on the model's features, and maybe a silicon agent knowledge base [29]. CogInfoCom's cognitive resonance role is to eliminate the "semantic wall" between systems, between carbon and silicon agents. The cognitive mapping methodologies may represent how a given stakeholder understands and perceives models, data, and the outcomes of data analytics pipelines. So, a person may assign a model with data to its antecedents and outcomes. The cognitive resonance as conceptual framework allows for assessing and discerning similarities and differences between models and data analytics pipelines, possibly elucidating that an explanatory system based on knowledge may yield concepts, and conceptual structures of mental models of stakeholders. However, the outcomes of the analyses are frequently difficult to understand or inconclusive [30]. So, data science systems have outperformed the carbon agents in terms of performance and mental capacity. Applications of data science pipelines include Decision Support Systems, Management/Executive Information Systems, and Manufacturing Execution Systems [31]. Complicated data science pipelines are unlike other mission-critical software in that they are difficult to test and analyze. The data analytics pipelines allow obtaining considerable data “features”. The intelligent explanatory subsystem, the system's knowledge bases, and knowledge discovery in data collections might construct the silicon agent's "expectations." CogInfoCom facilitates information communication between partners, particularly between the carbon agent and the CIS. CISs allow the silicon agent to attain cognitive resonance with the human actor in the eco-system of CISs Figure 3.

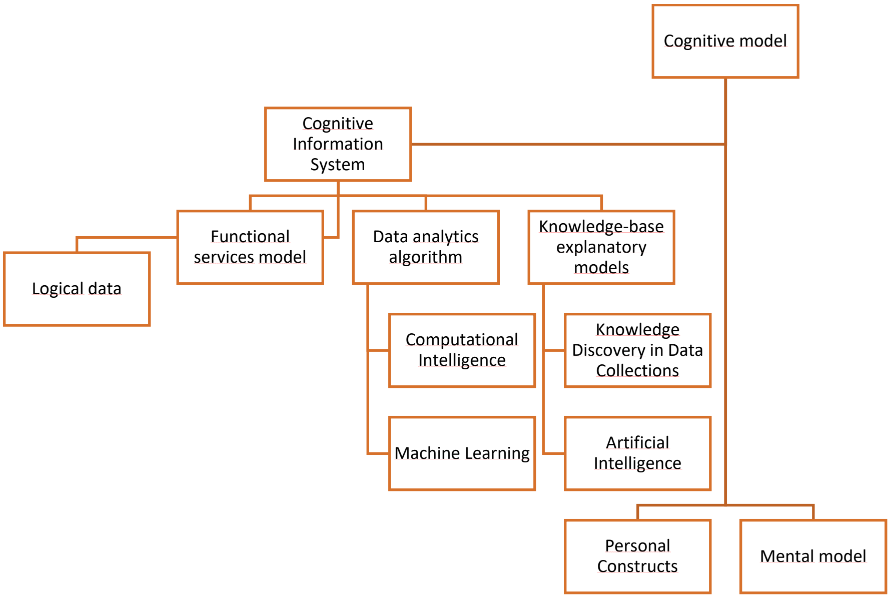


Figure 3
Achieving Cognitive Resonance

6 The Mental Model for the Carbon Agent

Following a document hierarchy, an overall idea map is in a document format, and the hierarchy of documents represents the deconstruction of the idea map into pertinent concept partitions. A document-centric strategy for the realization of idea maps and the associated hypergraph representation for finding significant patterns to produce cognitive resonance are now feasible [32, 22, 33]. To understand empirical data and the findings of data analytics, an information system might use cognitive-agent or cognitive architecture solutions [31]. The LIDA architecture is an option for establishing a cognitive architecture inside an Information System. A data analytics function in the form of an Information System may create the appropriate data representation for senior management. A business intelligence and data analytics solution can offer suitable information visualization and structure. Effective info-communication may achieve the desired organization and format. Recent business information systems allow CogInfoCom to interface with the carbon agent. Several methods exist for communication devices that can convey information to the carbon agent. To create a cognitive resonance between carbon agents and the information system in an organization, a multi-dimensional cognitive model might be developed. A subject-domain is a particular domain or context.

A conceptual map helps characterize and illustrate important conceptions and features of a topic area.

The *subject-domain* contains the notions and their attributes. The notions, attributes, statuses, and the relations between them can be represented [34].

Definition 1 *Subject-domain* consists of: A finite set of concepts that are represented by

$$\boldsymbol{NOTION} = \{notion_1, \dots, notion_n\} \quad (1)$$

The concepts are described by properties, the properties belong to certain attribute set $\boldsymbol{Property} = \{T_1, \dots, T_n\}$ of wich consist of the attribute types; The finite set of value ranges is $\boldsymbol{RANGE_{SET}} = \{R_1 \dots\dots R_k\}$ that contains the domain of value for every single type of attributes, T_i. where R_i is a countable infinite set.

$$Range : T_i \longrightarrow R_i \text{ , } R_i \quad (2)$$

Definition 2 *Hierarchy* within *Subject-domain*

Let $\boldsymbol{Notion\_Hierarchy_{s\_d}}$ designate the set of notion hierarchies that comprise the hierarchies within a *Subject-domain* where $\boldsymbol{Notion\_Hierarchy_{s\_d}} = \{n\_h_1, \dots, n\_h_n\}$. The relationship between notion hierarchies of *Subject-domain* can be described by directed edges that represent a *mapping* relationship between two hierarchies [29].

Definition 3. A Notion Hierarchy, $n\_h_i \in \boldsymbol{Notion\_Hierarchy_{s\_d}} = \{n\_h_1, \dots, n\_h_n\}$ can be represented as tree structure, directed graph. The relationship between elements of a notion hierarchy can be described with a mathematical relation, namely by partial ordering $R, n_l \; R \; n_g \Leftrightarrow$

$$if \; Property(n_l) \subset Property(n_g), \; \forall \, i, \; Range\left(Property(n_l)\right)(T_i) \subset \left(Property(n_g)\right)(T_i) \quad (4)$$

Definition 4. The hierarchy mapping between notion hierarchies of subject domains is for an association between a pair of notion hierarchies

$$n_{s\_d\,j_h} \in Notion_{Hierarchy_{s_{d_i}}}, n_{s\_d\,j_k} \in Notion_{Hierarchy_{s_{d_j}}} \qquad i \neq j,$$

$$Map_{hierarchy}: Notion_{Hierarchy_{s_{d_i}}} \longrightarrow Notion_{Hierarchy_{s_{d_j}}} \quad (5)$$

Definition 5. Similarity Correspondence is specified through the mapping between the two concept hierarchies

$$n_{s_{d}\,j_h} \in Notion_{Hierarchy_{s_{d_i}}}, n_{s_{d}\,j_k} \in Notion_{Hierarchy_{s_{d_j}}} \qquad i \neq j,$$

$$Correspondance: Notion_{Hierarchy_{s_{d_i}}} \times Notion_{Hierarchy_{s_d}} \longrightarrow \mathbb{R}^+ \quad (6)$$

The outlined model can be used to find the notions that can be exploited to build up an effective info-communication between the carbon agent and silicon agent, even when the silicon agent includes cognitive agents.

7 Reality and Expectations form CIS

It is vital to state clearly what is expected from CIS. As there are many unresolved or partly resolved challenges, the goal of CIS design must be decided. The need for a CIS be able to improvise, develop new hypotheses, and test them has been shown to be impractical. Humans can perceive and discover new information from the environment because they can assess seen facts effectively, and the human has the capability to generalize. However, those researchers who analyze difficult problems on how to be solved computationally, and categorize some problems as being intractable issues, do not give up instead they attempt to find heuristics solutions. Sarathy et al. in [35] stated that using CIS and AI are presently not reality CIS to make use of a variety of heuristics concurrently, as well as other assets and experiments, in order to solve the given hard issues:

(1) Related to capabilities and abilities

(2) Impasse detection - the ability to weigh the current situation against one's capabilities and abilities [36]

(3) Domain transformation and problem restructuring - in plan task revision, the effects of changing the state, including the goal and operators, have been formally examined [37, 38]

(4) Experimentation, learning through interaction with the world, taking exploration and reinforced learning into account [39, 40]

(5) Discovery detection - the ability to address difficulties in the face of unexpected occurrences via intelligent thinking that demonstrates autonomy [35]

(6) Domain extension - the ability to choose when and how to absorb additional information from a particular domain [38].

Nonetheless, the AI landscape rapidly changed [41, 42, 43]. These new algorithms and tools makes it possible to assist the cognitive resonance in complex processes of decision making, e.g. it makes it easier to generate visualizations and dashboards that fits the specific human agent according to the hypersensitivity requirements. Not long before, the intractable problems demanded to be solved demanded rough approximation or greedy algorithms or enormous computational performance. Nevertheless, the development in computer science and the hardware performance made it possible to tackle this problem in a reasonable way [44]. We can encounter fairly frequently these classes of problems in Management Information Systems and decision-making.

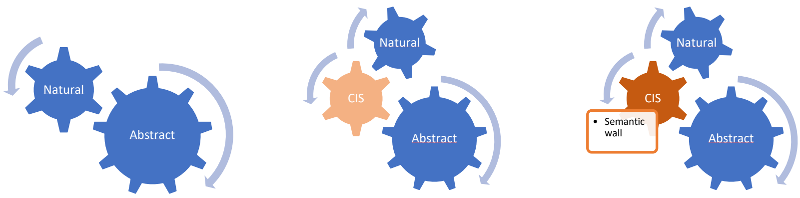
While some of the challenges have been overcome, no CIS exists that is capable of addressing a complicated task requiring all of the above-mentioned characteristics at the same time. The human brain translates observation-based anticipations into a decision-making process; as a consequence of the transformation, the human views the strategic choice as a possible conclusion as an "expectation" in the outcome. This approach may be taught to CIS through repeated loops of cognitive resonance and decision-making learning, enabling CIS to assist humans in strategic decision-making [14]. However, the traits indicated before, such as intuitiveness and interpretable improvisation, are unique to the human, a.k.a. carbon agent. In the case of CIS architecture, the amount of complexity must be considered. Simple jobs do not need a sophisticated technique, i.e., CIS. Although, developing CIS with expanded problem-solving behavior increases the difficulties associated with architecture, programming, and other aspects of CIS development that are tied to concerns. Lack of anticipated functionality of CIS has a detrimental effect on the holistic system approach in the case of CIS, thereby, the realization of the missing functional services is one of the critical assets that can orchestrate the synergy to facilitate information transmission.

8 Perspectives of the Architectural Cognitive Elements

According to Wang, "Cognitive Informatics (CI) is a transdisciplinary inquiry of cognitive and information sciences that utilizes an interdisciplinary approach to investigate the internal information processing mechanisms and processes of the brain and natural intelligence, as well as their engineering applications" [45]. The contextual perception is derived from the underlying model of CIS, the formation of hypotheses, and the process of continuous learning. Thus, the most critical characteristics of CIS are their capacity to carry out information exchange and the cognitive resonance generated by the contact, which enables CIS to raise their cognitive level. Wang established a framework for the representation of systems in Cognitive Informatics. "The Information - Matter - Energy (IME) Represent establishes a link between the natural world (NW) and the abstract or perceptual world (AW), where matter (M) and energy (E) model the NW and information (I) models the AW." [45]. Thus, by using formal techniques of information processing, the environment is brought inside the sphere of human intellect, which is the subject of Cognitive Informatics. Because the content of an IS comprises information that is composed of both data and programs, we regard the second cycle of learning mechanisms through HCI to be the basis for discriminating, owing to the fact that the first circle had no inescapable effect on the NW, AW, or CIS.

Interpretations: (1) CIS equivalent of AW; (2) CIS wedged entity between NW and AW; (3) CIS a separated entity, therefore out form NW and AW.

1. *CIS equivalent of AW:* In this example, since CIS provides a mathematical description of AW, it is the CIS equivalent of AW. In the second learning cycle, the cognitive resonance that HCI might induce may enhance AW/CIS cognitive capacity in the same way as it increases NW cognitive level. The information communication medium is adaptable and compatible with the path of energy and information transmission between NW and AW. a. Figure 4.



a b c

Figure 4

a., CIS as a representation of Abstract World ;b., CIS as a communication medium; c., semantic wall"

2. *CIS wedged entity between NW and AW*: In this situation, we wedge CIS between NW and AW. As a result, CIS makes use of energy and matter at the human-computer interface. They are seen as input into the abstract world (AW) through cognitive resonance, and subsequently as output into the natural world (NW). The natural environment has the ability to alter and stretch matter, as well as enhance the energy associated with these activities. As a result of cognitive improvement in the human brain, the learning process may increase the information content of the physical world (NW). The expanded capacity of the natural world (NW) assures that the input for (AW) is modified, and therefore it is boosted as well. The cycle of CIS is iterative in nature, aiming to develop cognition at both levels. The path of communication correlates to a degree to the path of energy and information transfer. 4.b.

3. *CIS a separated entity, therefore out form NW and AW:* In this case, CIS is a distinct entity, distinct from NW and AW: In this situation, each imputation of the NW increases the AW's input, enabling inputs from the AW to the natural world to grow the NW's breadth, or vice versa. Similarly, if we consider the cognitive system as a mechanism and incorporate all aspects of a quasi-third dimension in which our two-dimensional realm transfers and collects information via infocommunication, the two components grow concurrently, resulting in an increase in cognitive abilities and knowledge. Although the communication medium is distinct from the pathways connecting NW and AW, it has an indirect effect on the flow of information and energy through infocommunication Figure 4 c. According to Wang [45, 46] there are 19 distinct CI elements in the software-related relationship; however, the list might be expanded to include the following:

20. Adaptive use of information communication as a channel, technique, and instrument, leveraging the synergy formed throughout HCI as a cognitive resonance across dimensions, regardless of the IME model's position of CIS."

Thus, the architecture places a premium on components that focus on learning via HCI, as traditional machine learning methodologies and heuristic, statistical approaches produce expected and reasonable output, but do not always produce unexpected but reasonable results when used by humans in CIS computing. This surprising but plausible outcome puts us closer to the imagined CIS, which seems to be as natural as possible when viewing people as a natural entity.

Understanding human cognition from an architectural perspective, where communication is done by sensors of humans and processes within the human body, from which relevant disciplines have considerable but incomplete knowledgeBut all components that invisibly support human cognition are or part of it, affecting the result and/or flowing via the channel of InfoComCIS enhanced with cognitive resonance through info-communication, making the system comparable to people. In the absence of cognitive resonance, the system remains a system devoid of cognitive features that would replicate genuine human behavior.

Create artificial systems with human-like abilities: Because of the absence of formalization, it is likely that information-communication will be excluded from architecture. Humans are consistent in their thinking, yet there is an element of human cognition termed the adaptive unconscious. This idea is connected to unconsciously reasoning and making judgments. This is one of the obstacles of mimicking human cognition using CIS. However, the adaptive unconscious brain process is not available to awareness. It is a set of survival principles that humans evolved.

According to Gladwell, it is “thin thinking”, when the brain adapts quickly to its environment [47].

Cognitive resonance enables the system to evolve human knowledge through Human-Computer Interaction. If we use information theory, we must change Wang's models [48]. To sum it up, CISs are components of the Digital Universe, made up of bits that are the binary description of CISs. The data of CISs that contain the static and the dynamic, executable data are engulfed by information forms to be interpreted by the carbon agent. The data from nature expands the information richness of the Digital Universe within the area of abstraction in Fig. 5. Because the code of programs and data combined together defines the degree of complexity of the information, data retrieval processes and data processing functions cannot increase the complexity of the information contained in an Information System (see [49]).

A CIS is a collection of data and algorithms that compose the system's information content. The computation may generate data that are not yet gathered into the system. Nonetheless, the computing process using the given data does not expand the system's overall information scope. The communication of data from the Digital Universe to the natural world might enhance the carbon agent's knowledge via comprehension and understanding of the data's significance. The human actor interprets the information supplied by formations to produce actionable knowledge. The abstract universe is divided into two parts: the collection of Information Systems and the data contained in formations and identified by bits. The other entity is a collection of CISs that includes modern data manipulation and visualization technologies, as well as software tools to achieve high cognitive resonance between humans (carbon agents) and machines (the silicon agent).

9 Architectural Aspects of CogInfoCom

Baranyi et al. [2] define CogInfoCom as devices and networks that may dynamically allocate resources and functions. CIS can develop information dynamically and intelligently, but UBMSS lacks these capabilities [3]. These facts underscore the importance of cognitive architecture, cognitive functions, and the integration that allows cognitive entities to evolve. On the other hand, there is a perspective that human cognition and intellect are emergent traits that cannot be isolated from our physical, biological and neurophysiological origins [50]. However, the social and technical context of our interactions with other people and ICT components influences our mental and physical actions [50, 51]. This element underlines the importance of cognitive resonance, which allows both humans and CIS to progress cognitively. Only a good CIS can use CogInfoCom in this way. The system's design focuses on rendering information about both sides of the cosmos, as well as information appearance and interpretation in humans and carbon agents.

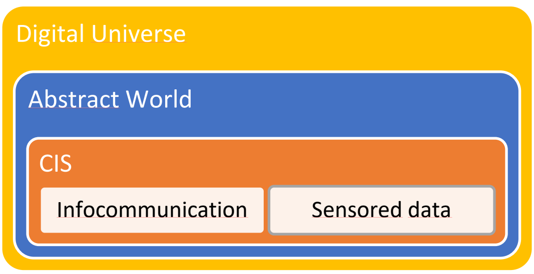


Figure 5
CogInfoCom in the context of the Digital Universe and Cognitive Information Systems

Conclusions

Uncovering the underlying cognitive structure in Information Systems, may benefit from a systematic design strategy for architecture creation. These methodologies allow for exact characterization of complex business situations, including multidisciplinary areas such as cognitive sciences, information systems analysis and design, formal architectural methods, and Data Science, including, other domains not covered in this study. Small and medium-sized businesses may use the paper's strategy to create CISs by combining open-source software solutions with other components. To increase the utility of information, knowledge, and learning, CogInfoCom is used to support and use cognitive science outcomes. The Enterprise Architecture facilitates information interchange and communication amongst CIS components. To govern the overarching data processing and information exchange to choreograph the following tasks, modern Information Systems contain various elements that force cognitive activity, from a human agent. Electronic devices (actuators, sensors, etc.) are now part of modern Information Systems. Edge and Fog computing convert data generated by IoT devices. Unstructured data is ingested into Data Lakes; structured data is ingested into Data Warehouses. The carbon agent can utilize the vast quantity of information if the produced data is shown using the synergy among varied methodologies and algorithms. To make sense of the data, Data Science should be used to extract it and change it. It promotes a bidirectional information stream to achieve cognitive resonance on the carbon agent's side. To give meaningful feedback for the carbon agent, silicon agents may establish cognitive resonance by properly representing the analog and digital universes.

The attainment of cognitive resonance, by an effective CogInfoCom, will improve the quality of Information Systems and increase their dependability and trustworthiness. CogInfoCom is an integrated cognitive process where the human brain's capabilities are increased not just via equipment but also by contact with any CIS. Cognitive Resonance enhances HCI knowledge and efficacy, making it more relevant, and so, contributing to part of CogInfoCom.

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References

[1] P. C. A. Baranyi, Cognitive infocommunications: Coginfocom, 11th ieee international.

[2] P. Baranyi, A. Csapo and G. Sallai, Cognitive Infocommunications (coginfocom), Heidelberg: Springer International Publishing, 2015.

[3] P. Baranyi, A. Csapo and P. Varlaki, "An Overview Of Research Trends In Coginfocom," in *INES 2014 - IEEE 18th International Conference on Intelligent Engineering Systems, Proceedings*, 2014.

[4] Suzić, S., Delić, T., Pekar, D., Delić, V., Sečujski and M., Style transplantation in neural network based speech synthesis, Acta Polytechnica Hungarica, 2019.

[5] Tóth, J., Tornai, R., Labancz, I., Hajdu and A., Efficient visualization for an ensemble-based system, Acta Polytechnica Hungarica, 2019.

[6] Kanazawa, M., Ito, A., Yamasawa, K., Kasahara, T, Kiryu, Y., Toyama and F., Method to predict confidential words in japanese judicial precedents using neural networks with part-of-speech tags), Infocommunications, 2020.

[7] Kiryu, Y., Ito, A., Kanazawa and M., Recognition Technique of ConfidentialWords Using Neural Networksin Cognitive Infocommunications., Acta Polytechnica Hungarica, 2019.

[8] J. A. Zachman, "A Framework For Information Systems Architecture," *IBM systems journal,* vol. 26, p. 276–292, 1987.

[9] J. Smith, Manager of multimedia and vision at ibm research.

[10] B. Molnár and Á. Tarcsi, "Design And Architectural Issues Of Contemporary Web-based Information Systems," *Mediterr. J. Comput. Netw,* vol. 9, p. 20–28, 2013.

[11] J. Hurwitz, M. Kaufman, A. Bowles, A. Nugent, J. G. Kobielus and M. D. Kowolenko, Cognitive Computing And Big Data Analytics, Wiley Online Library, 2015.

[12] L. Ogiela and M. R. Ogiela, "Cognitive Systems For Intelligent Business Information Management In Cognitive Economy," *International Journal of Information Management,* vol. 34, p. 751–760, 2014.

[13] B. Molnár and D. Mattyasovszky-Philipp, "Cognitive Information Systems–artificial Intelligence & Management Decisions," in *Proceedings of the 12th IADIS International Conference Information Systems 2019*, Utrecht, 2019.

[14] B. Molnár and D. Őri, Towards A Hypergraph-based Formalism For Enterprise Architecture Representation To Lead Digital Transformation, Cham: Springer, 2018, p. 364–376.

[15] V. Raja, "A Theory Of Resonance: Towards An Ecological Cognitive Architecture," *Minds and Machines,* vol. 28, p. 29–51, 2018.

[16] V. L. Lemieux and T. Dang, Building Accountability For Decision-making Into Cognitive Systems, Springer, 2013, p. 575–586.

[17] C. J. MacLellan, E. Harpstead, I. I. I. R.P. Marinier and K. R. Koedinger, "A Framework For Natural Cognitive System Training Interactions," *Advances in Cognitive Systems ,* vol. 2018, pp. 177–-192, 2018.

[18] S. Franklin, T. Madl, S. D\textquoterightmello and J. Snaider, "Lida: A Systems-level Architecture For Cognition, Emotion, And Learning," *IEEE Transactions on Autonomous Mental Development,* vol. 6, p. 19–41, 2013.

[19] A. Josey, Togaf Version 9.1-a Pocket Guide, Van Haren, 2016.

[20] D. Kahneman, Thinking, Fast And Slow, Macmillan, 2011.

[21] U. Faghihi, C. Estey, R. McCall and S. Franklin, "A Cognitive Model Fleshes Out Kahneman's Fast And Slow Systems," *Biologically Inspired Cognitive Architectures,* vol. 11, p. 38–52, 2015.

[22] B. Molnár, A. Béleczki and A. Benczúr, "Information Systems Modelling Based On Graph-theoretic Background," *Journal of Information and Telecommunication,* vol. 2, no. 1, p. 68–90, 2018.

[23] B. Molnár and A. Benczúr, "The Application of Directed Hyper-Graphs for Analysis of Models of Information Systems," *Mathematics,* vol. 10, p. 759, February 2022.

[24] B. Horváth, J. Szép and A. Borsos, "Built Environment Information Platform: A conceptual introduction," in *IEEE International Conference on Cognitive Infocommunications (eds.) 12th IEEE International Conference on Cognitive Infocommunications (CogInfoCom 2021) : Proceedings* , IEEE , 2021, p. 98–889.

[25] F. Hajdu, R. Kuti and C. Hajdu, " Simulation-aided Intelligent Evacuation Planning," in *IEEE International Conference on Cognitive Infocommunications (eds.) 12th IEEE International Conference on Cognitive Infocommunications (CogInfoCom 2021) : Proceedings* , vol. 2, IEEE , 2021, p. p.

[26] A. Torma, B. Hanula and P. Németh, " Multilevel Sustainability - Extended analyzing method to evaluate climate protection efficiency," in *IEEE International Conference on Cognitive Infocommunications (eds.) 12th IEEE*

International Conference on Cognitive Infocommunications (CogInfoCom 2021) : Proceedings , vol. 6, IEEE , 2021, p. p.

[27] G. A. Kelly, The Psychology Of Personal Constructs. Volume 1: A Theory Of Personality., New York: WW Norton and Company, 1955.

[28] K. Siau and X. Tan, “Information systems requirements determination and analysis: A mental modeling approach,” *AMCIS 2003 Proceedings,* p. 170, 2003.

[29] L. Ogiela, Cognitive Information Systems In Management Sciences, Boston ed., Bosto: Academic Press, 2017.

[30] J. d. L. F. A. H. T. Moreira, A general introduction to data analytics., Wiley Online Library, 2019.

[31] P. Oleksyk, M. Hernes, B. Nita, H. Dudycz, A. Kozina and J. Janus, Supporting Investment Decisions Based On Cognitive Technology, Heidelberg: Springer, 2020, p. 41–59.

[32] N. Kasabov, "Evolving Intelligent Systems For Adaptive Multimodal Information Processing," in *Evolving Connectionist Systems: The Knowledge Engineering Approach*, London, 2007.

[33] B. Molnár and A. Benczúr, "Modeling Information Systems From The Viewpoint Of Active Documents," *Vietnam Journal of Computer Science,* vol. 2, no. 4, p. 229–241, 2015.

[34] D. Mattyasovszky-Philipp, A. Putnoki and B. Molnár, The Unrepeatable Human Mind—Challenges in the Development of Cognitive Information Systems—What Makes a Machine Human?, MDPI Electronics, 2022.

[35] V. Sarathy and M. Scheutz, "Macgyver Problems: Ai Challenges For Testing Resourcefulness And Creativity," *Advances in Cognitive Systems,* vol. 6, p. 31–44, 2018.

[36] C. Bäckström, P. Jonsson and S. Ståhlberg, "Fast Detection Of Unsolvable Planning Instances Using Local Consistency," in *Sixth Annual Symposium on Combinatorial Search*, 2013.

[37] M. Göbelbecker, T. Keller, P. Eyerich, M. Brenner and B. Nebel, "Coming Up With Good Excuses: What To Do When No Plan Can Be Found," in *Twentieth International Conference on Automated Planning and Scheduling*, 2010.

[38] A. Herzig, M. V. de Menezes, L. N. D. Barros and R. Wassermann, "On The Revision Of Planning Tasks.," in *ECAI*, 2014.

[39] T. Hester and P. Stone, "Intrinsically Motivated Model Learning For Developing Curious Robots," *Artificial Intelligence,* vol. 247, p. 170–186, 2017.

[40] D. Pathak, P. Agrawal, A. A. Efros and T. Darrell, "Curiosity-driven Exploration By Self-supervised Prediction," in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition Workshops*, 2017.

[41] B. Meyer, *What Do ChatGPT and AI-based Automatic Program Generation Mean for the Future of Software,* 2022.

[42] J. Roschelle, *The ChatAlgebra Educational Revolution,* 2023.

[43] M. Welsh, "The End of Programming," *Communications of the ACM,* vol. 66, p. 34–35, December 2022.

[44] L. Fortnow, "Fifty years of P vs. NP and the possibility of the impossible," *Communications of the ACM,* vol. 65, p. 76–85, January 2022.

[45] Y. Wang, "The Theoretical Framework Of Cognitive Informatics," *International Journal of Cognitive Informatics and Natural Intelligence (IJCINI),* vol. 1, p. 1–27, 2007.

[46] Y. Wang, "The Theoretical Framework of Cognitive Informatics," in *Novel Approaches In Cognitive Informatics And Natural Intelligence.*, 2009.

[47] M. Gladwell, Blink!, USA Time Warner, 2005.

[48] Y. Wang, "On The Informatics Laws And Deductive Semantics Of Software," *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews),* vol. 36, p. 161–171, 2006.

[49] A. Benczúr and B. Molnár, "On The Notion Of Information–info-sphere, The World Of Formations," in *2018 9th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, 2018.

[50] T. W. Deacon, Incomplete Nature: How Mind Emerged From Matter, WW Norton & Company, 2011.

[51] J. Hollan, E. Hutchins and D. Kirsh, "Distributed Cognition: Toward A New Foundation For Human-computer Interaction Research," *ACM Transactions on Computer-Human Interaction (TOCHI),* vol. 7, p. 174–196, 2000.