



26th International Conference on Knowledge-Based and Intelligent Information & Engineering Systems (KES 2022)

Experience-based Intelligence Augmentation with Decisional DNA: Upcoming Direction

Edward Szczerbicki^a*

Cesar Sanin^b

^a*The Gdansk University of Technology, 80-233 Gdansk, Poland*

^b*Australian Institute of Higher Education, Sydney, Australia*

Abstract

Intelligence amplification systems and technologies have gained significant interest from academia and industry during the past few decades. One of the main reasons behind this trend is the fact that most experts agree that truly intelligent artificial system is yet to be developed. The question increasing often asked is this: Is full replication of human intelligence desirable key aim in intelligence related technology and research? In this context, the concept of Augmented Intelligence, also known as Cognitive Augmentation or Intelligence Amplification (IA) comes into play. One of the main reasons behind this interest in this concept is the potential of such technologies to revolutionize human life as they intend to work under complex decision-making environments, adapting to a comprehensive range of unforeseen changes, and exhibiting prospective behavior. The combination of these properties aims to enhance human capabilities and create more intelligent and efficient human-centered environments. In this paper we discuss how Decisional DNA (DDNA), a multi-domain knowledge structure that has the Set of Experience Knowledge Structure (SOEKS) at its core can be utilized as an experience-based intelligence augmentation in a number of different domains.

© 2022 The Authors. Published by Elsevier B.V.

This is an open access article under the CC BY-NC-ND license (<https://creativecommons.org/licenses/by-nc-nd/4.0>)

Peer-review under responsibility of the scientific committee of the 26th International Conference on Knowledge-Based and Intelligent Information & Engineering Systems (KES 2022)

Keywords: Decisional DNA; Knowledge Management; Decision Making; Intelligence Augmentation

* Corresponding author. Tel.: + 48 58 347 21 95

E-mail address: esz@zie.pg.gda.pl

1. Why Augmented Intelligence and our Technology to Implement It

The concept of Augmented Intelligence, also known as Cognitive Augmentation or Intelligence Amplification (IA) has been first mentioned in [1]. For any specific application, humans being and machines have both their own strengths and weaknesses. Machines are very efficient in numerical computation, experience-based information capture, statistical reasoning, with almost unlimited storage. On the other hand, humans have their own cognitive capabilities, which includes consciousness, problem-solving, learning, planning, reasoning, creativity, and perception. These cognitive functions allows humans to learn from last experiences and use this experiential knowledge to adapt to new situations and to handle abstract ideas to change their environment. Therefore, the combination of both human experiential knowledge supported by experience-based information collected by a system can be used to enhance smartness and for improved decision-making [2].

The implementation of amplification technologies requires the design of functionalities for knowledge engineering (acquisition and formalism, reasoning about events for decision making, and goal specification, all of which are concerned with the semantics of the relationship between the human agents and their environments i.e. context defined by experience [3]. These functionalities direct augmentation systems towards purposeful behaviour, adaptability, anticipation, such as human beings.

In this context, knowledge and leaning are central to augmentation technologies. To be readily articulated, codified, accessed and shared, knowledge must be represented in an explicit and structured way. In addition, the choice of a suitable representation greatly facilitates obtaining methods that efficiently learn the relevant information available. Therefore, an appropriate knowledge representation is crucial for the success in designing of any intelligence amplification system. To address this issue an experience-based multi-source knowledge representation without limiting its operations to a specific domain has been proposed [4]. This representation supports mechanisms for storing and reusing experience gained during decision-making processes through a unique, dynamic, and single structure called Decisional DNA (DDNA) [5]. DDNA makes use of Set of Experience (SOE) in an extended version for the use of storing formal decision events related to a given decision making situation. DDNA and SOE provide a knowledge structure that has been proven to be multi-domain independent [6].

1.1. SOE and DDNA

For the sake of completeness, SOE and DDNA are very briefly introduced here [7]. Set of Experience Knowledge Structure (SOEKS) is a knowledge representation structure created to acquire and store formal decision events in a structured and explicit way. It is composed by four key elements: variables, functions, constraints, and rules (Fig. 1.)

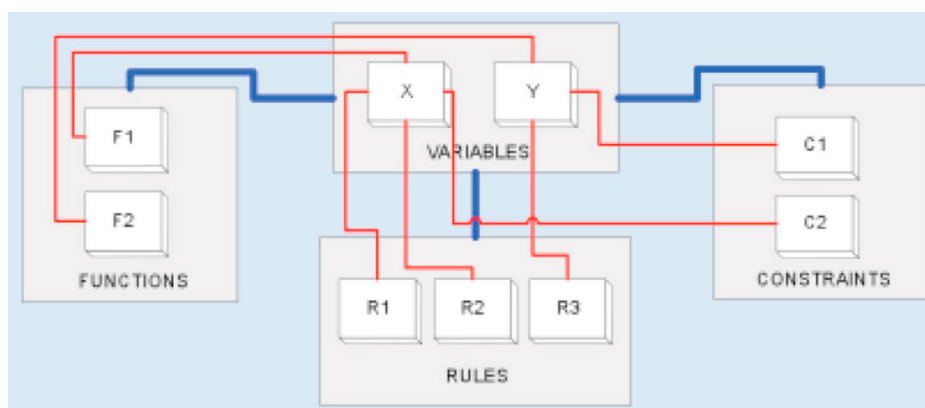


Fig. 1. The structure of set of experience [7,8]

Variables are commonly used to represent knowledge in an attribute-value form, following the traditional approach for knowledge representation. Functions, Constraints, and Rules of SOEKS are ways of relating variables.

Functions define relationships between a set of input variables and a dependent variable; thus, SOEKS uses functions as a way to create links among variables and to build multi-objective goals. Constraints are functions that act as a way to limit possibilities, limit the set of possible solutions and control the performance of the system in relation to its goals. Lastly, rules are relationships that operate in the universe of variables and express the condition-consequence connection as “if-then-else” and are used to represent inferences and associate actions with the conditions under which they should be implemented [6]. Rules are also ways of inputting expert knowledge into the system. The Decisional DNA consists is a structure capable of capturing decisional fingerprints of an individual or organization and has the SOEKS as its basis. Multiple Sets of Experience can be collected, classified, organized and then grouped into decisional chromosomes, which accumulate decisional strategies for a specific area of decision making activities. The set of chromosomes comprise, finally, what is called the Decisional DNA (DDNA) [5].

2. DDNA Experience Administration in Practice

DDNA technology applications operate through a dedicated manager. The Decisional DNA Manager is a software platform for experience administration [8]. This tool supports collecting, storing, improving, and reusing experience from formal decision events. It can be used to analyse, query, consolidate and administer semantic experience captured by the means of SOE and Decisional DNA. Additionally, the software allows the exportation of semantic experience into XML and OWL to enhance knowledge sharing capabilities. The complete set of the Manager functionalities includes:

- DDNA negotiation process
- DDNA based data mining for knowledge discovery
- SOE similarity measure for DDNA formation
- SOE ontology and its reflexiveness enhancement
- SOE Java class with ontology system
- DDNA based heuristics techniques and DDNA Genetic Algorithm

This Manager tool has been developed using Java SE 6 [9]. It uses JGraph to provide proper visualization capabilities. The Substance Look and Feel Library was used to create an attractive Graphical User Interface (GUI). Basic features of the DDNA Manager are illustrated in Fig.2.



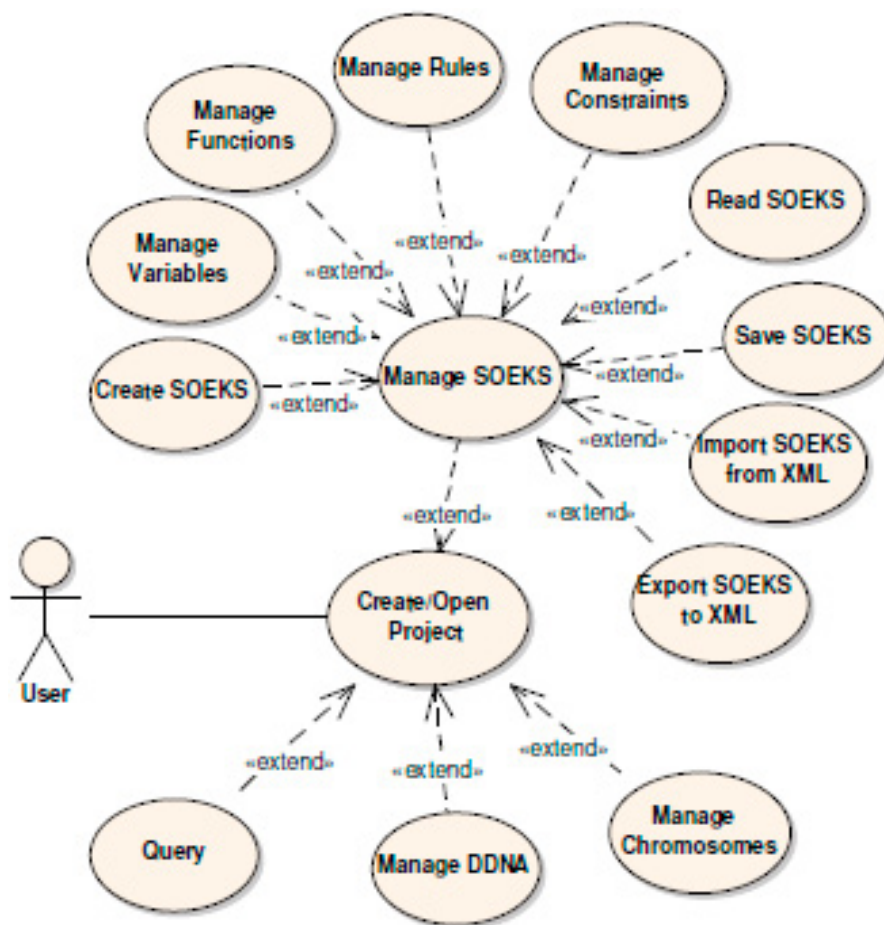


Fig. 2. DDNA Manager basic features

With graph visualisation library the Logical Viewer was designed to be used to demonstrate how a particular SOEKS is organised in a graphic, user friendly, way (Fig.3.)

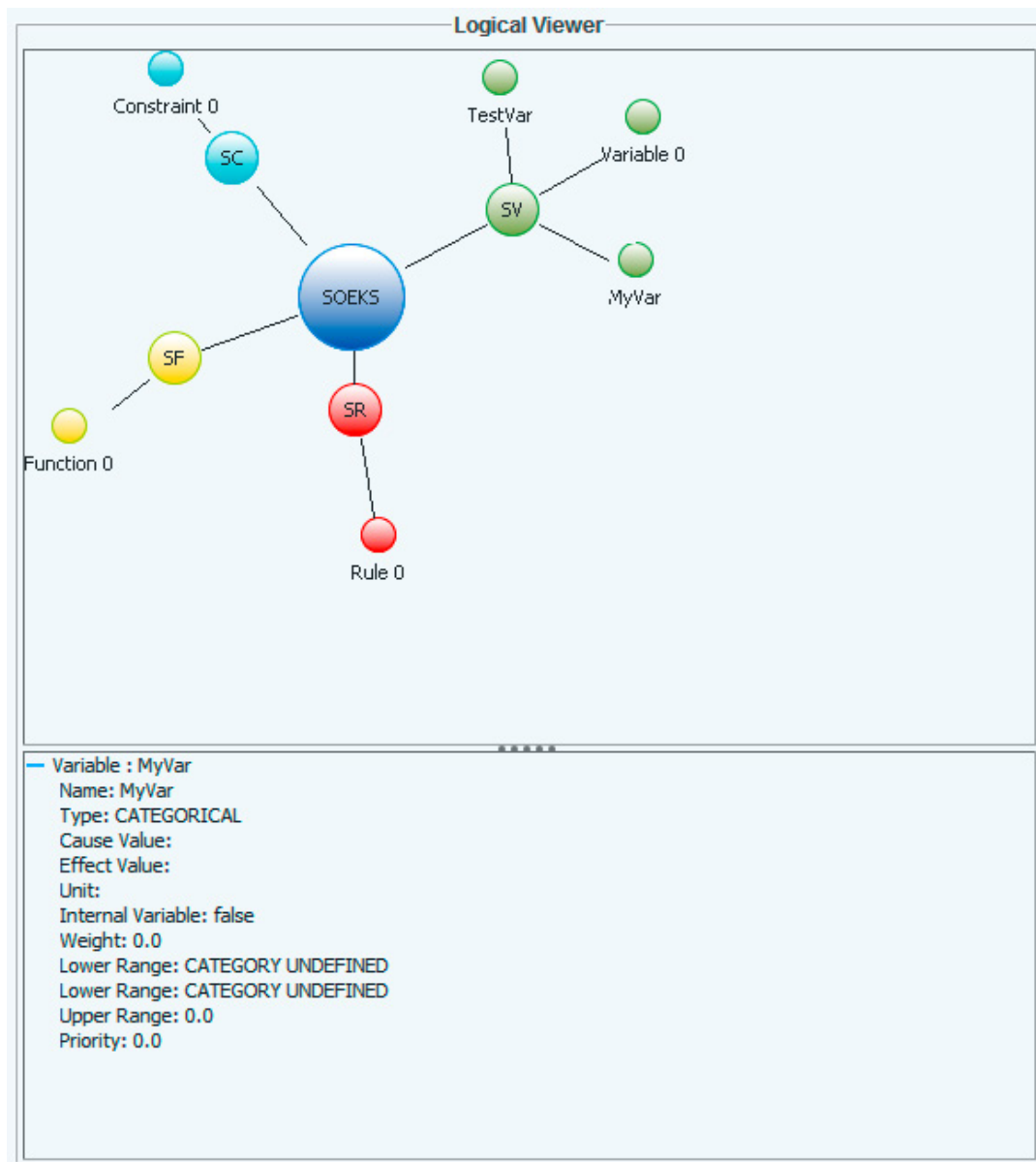


Fig. 3. DDNA Manager Visualization [8]

Logical Viewer in Fig.2. comprises two parts with upper and lower boxes. At the upper part, it exhibits the structure of the SOEKS, and at the lower part, the attribute values of a certain node in the SOEKS structure can be read in a tree-shape view.

DDNA Manager was experimentally tested and verified for parsing time, searching time, and similarity time, which proved that it can handle large amounts of data in a time efficient manner as required by an artificial “thinking mechanism” that can amplify human intelligence.

2.1. SOE and DDNA applications

Decisional DNA has been applied in different domains augmenting capabilities, facilitating smart knowledge

management, and engineering processes inside decision-making (Table 1.)

Table 1. SOE-DDNA in various domains in chronological order.

Application/Domain	Reference
Implementation of Decisional Trust and Reliability	[10]
Virtual Engineering	[11]
Geothermal Energy, Renewable Energy and Net Income	[12]
Workflow-Centred Experience Management	[13]
Embedded Systems/Robotics	[14]
Knowledge Quantification	[15]
E-Decisional Community	[15]
Business Experience Management	[16]
Continuous Improvement in Experience Feedback	[17]
Interactive/Smart TV	[18]
Decision Support Medical Systems for Alzheimer and Breast	[19]
Cancer Diagnosis	
Virtual Engineering Object, Virtual Engineering Process, Virtual	[20]
Engineering Factory for Industry 4.0	
Innovation Amplification	[21]
Industrial Hazard Control	[7]

Table 1. presents domains and related references covering in a very comprehensive way detailed SOE and DDNA based research and applications. The selected references are for the sake of completeness and for further reading to gain deeper understanding of the technology that undertakes to systematically create, capture, evolve, reuse, and distribute decisional experience of work processes in any organization, preventing important decisional steps from being forgotten in the daily operation tasks, and supporting a path towards appropriate automation for frequently recurring decisional tasks. Capturing the experience of every decision made in an explicit representation form and reusing it, are highlighted as the major significances of this technology [22,23,24]. Experience has made species to survive and cultures to prevail, as experience makes organizations to succeed. SOEKS and DDNA allow building up the fingerprints of an organization by implementing a model for transforming information into knowledge.

2.2. From individual to collective experience-based Intelligence Augmentation

The newest and probably the furthestmost large-scale DDNA extension is the Idream.Technology platform (<https://www.idream.technology>) (Fig.4.) We are developing social digital platform using collective experience. This DDNA-based application, which commences in May 2022 after comprehensive one year long design, testing, and validation, projects personalized road-maps to achieve purposes, goals, and aims taking into account

individuals' personalities and circumstances. Specific areas of human activities covered within the platform include travel, education, acquisition, and well-being.

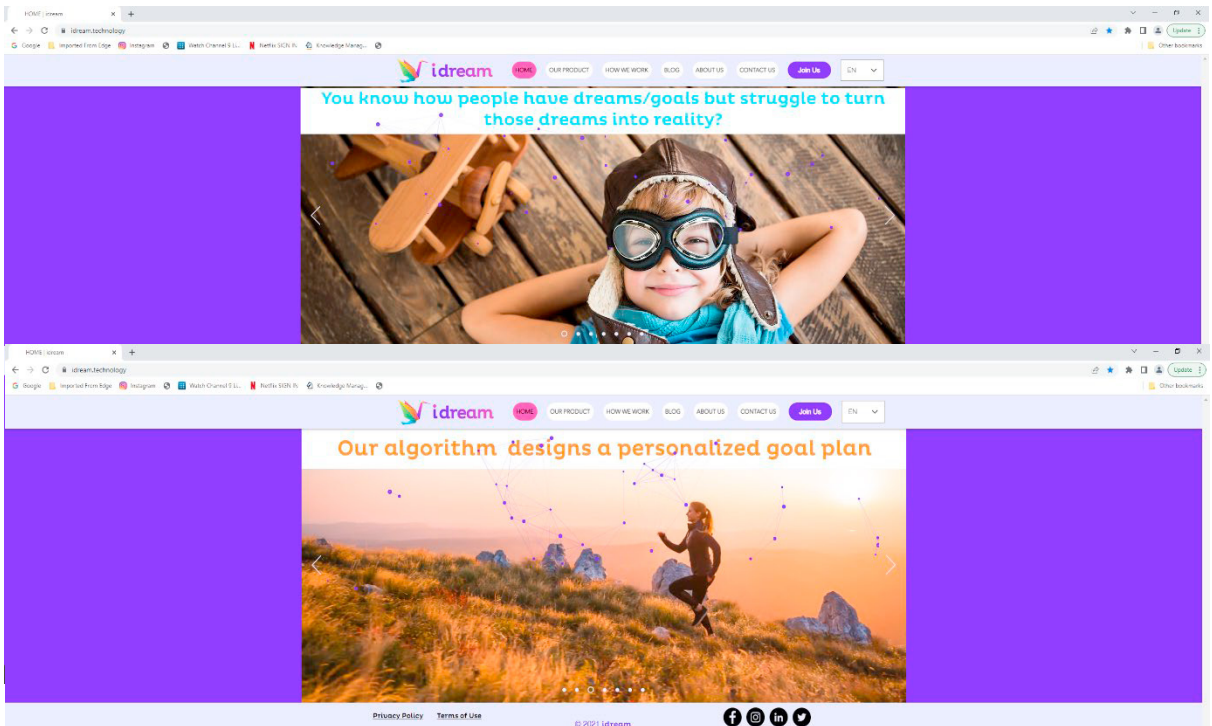


Fig.4. Screenshot of Idream.Technology home site: <https://www.idream.technology>

The popular existing social platforms personalize members' profiles classifying them by purchasing patterns or consumption of web content. Idream.Technology goes further because it mixes human intelligence with artificial intelligence, identifying how people make decisions. It captures, integrates, stores and reuses thousands of experiences occurring during the process of achieving dreams or goals. In other words, it uses collective decision-making experience and applies it to amplify the individual one. As the result, dreamers's profile is presented with a systematic procedure to follow in order to achieve their personal dream or objective.

The main technique researched to be applied in above procedure is the DDNA related similarity between Sets of Experience [25, 26, 8]. A common approach for a similarity metric between objects is defined in terms of a notion of distance (i.e., a geometric approach), and it is called a multidimensional scaling. A data object is represented by its coordinates in a similarity space. Thus, similarity, in that case, is given by the distance between objects in the space. In the proposed platform the distance measure between user profiles was considered part of the Minkowskian family distance metrics, i.e. the Euclidean and Hamming metrics. The Minkowskian approach takes two attribute vectors, says objects, s_i and s_j and calculates the similarity measure d as follows:

$$d_{ij} = \left[\sum_k w_k |s_{ik} - s_{jk}|^r \right]^{1/r} \quad (1)$$

where w_k is the weight given to the k^{th} attribute, and r is a parameter that determines which of the family of metrics is used. $r = 2$ corresponds to the Euclidean metric; $r = 1$ results in the City-Block, Taxi-Cab, or Manhattan metric; while as $r = \infty$ is the Supremum or Maximum metric [27]. Based on the above formula, we established similarity



metric for all 26 variables describing each user's Sets of Experience. Because these variables can be quantitative (continuous or discrete) and/or qualitative, prior to the estimation of the similarity measure, a prearranging process was performed over the qualitative variables, such as assigning numerical values or class values to each category.

Given a pair of Sets of Experience E_i and $E_j \in S$, we generated a similarity metric of the variables called $S_V \in [0, 1]$ by calculating the distance measure between each of the pairwise attributes $k \in E_i$ and E_j . The Euclidean distance measure has been selected based upon its simplicity and extended use. For $S_V=1$ the Sets of Experience (user profiles) are identical; when $S_V=0$ they are totally different [8]. In conclusion, similarity measures worked out establish an element of analysis among user profiles, making them comparable and classifiable. Consequently, data objects, or in our case Sets of Experience containing knowledge about user profiles, can be used as comparable elements for helping in the platform related decision-making process, i.e. reusing experience of various users. Thus, in Idream.Technology platform the similarity notion is applied to the distance between variables describing profiles of each participating member of Idream.Technology community. The most similar profiles are chosen by the system to assist in the creation of successful path to reach the goals set up by others. Fig.5. presents the screenshot of similarity engine in action.

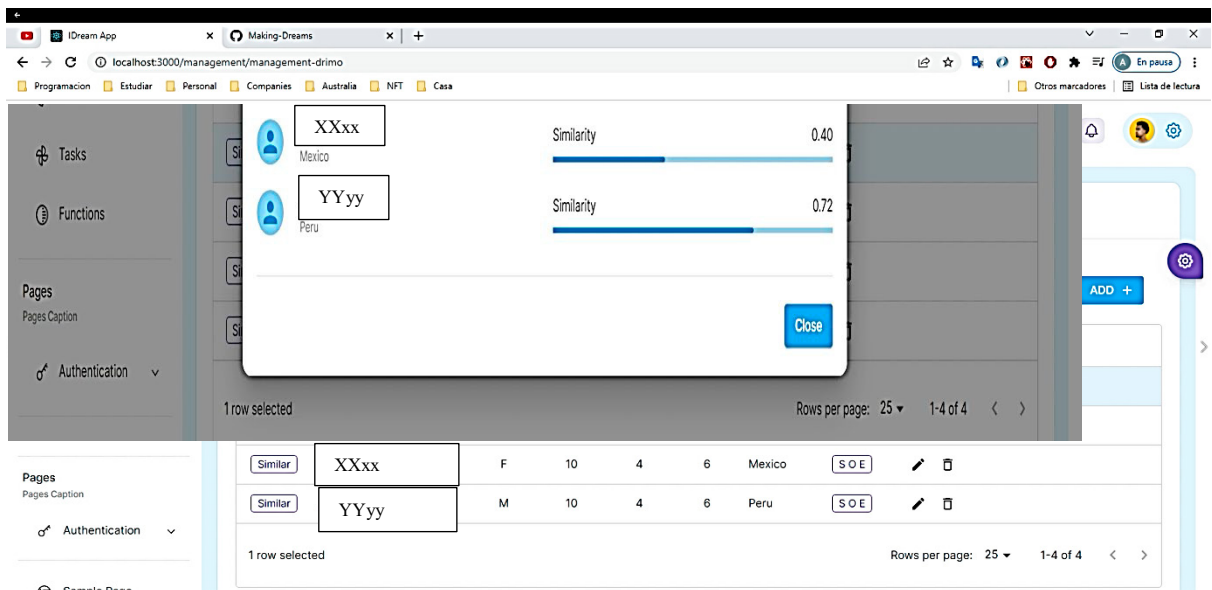


Fig.5. Similarity selection

Idream.Technology is a start-up hi-tech company which was launched in May of 2021 and is ready to offer its smart enhancement of dedicated coaching services. It provides DDNA technology based tools to enhance peoples' sustainable development. It addresses global societies by covering English and Spanish speaking regions of the world.

3. Future Outlook

Set of Experience and Decisional DNA concepts are at the beginning of their advance but are already making a difference to intelligence augmentation. By using this technology, a number of significant and innovative aims are attained in the current state of the system:

- Application of a non-domain-dependent knowledge structure,
- Use of an experience-based knowledge structure able to store qualitative and quantitative decisional elements,
- Integration different intelligent and decision-making systems by the means of using the experience-based

knowledge structure,

- Implementation and assessments for uncertainty, incompleteness, and imprecision by the means of the experience-based knowledge structures, and
- Application of Augmented Intelligence by allowing the combination of automatic decisions and decisionmaker's priorities in order to perform and choose the best solution among a collection of combined experience-based solution.

Some further steps in our DDNA-SOE related research will include:

- Evaluation and comparison of different strategies for Decisional DNA repository storage and query, and
- Developing mechanism to integrate DDNA with multimedia applications in a way that would allow for collection of formal decision events defined by images and sound.

Generally, future integration of various DDNA extensions would provide an intelligent and sustainable Internet application environment that enables virtual roles (mechanisms that facilitate interoperation among users, applications, and resources) to effectively capture, publish, share and manage explicit knowledge resources. It would also provide support for on-demand services creating vast commercial potential for our technology. Through our approach to knowledge representation and formalization embedded in the concept of Decisional DNA, the future DDNA-based knowledge grid would incorporate epistemology and ontology to reflect human cognition characteristics and adopt the techniques and standards developed during work toward the next-generation, beyond-semantic web.

References

- [1] Ashby, W. R. (1961). An introduction to cybernetics. Chapman & Hall Ltd. New York
- [2] Pathak, N. (2017). The Future of AI. In Artificial Intelligence for. NET: Speech, Language, and Search (pp. 247-259). Apress, Berkeley, CA.
- [3] Sanin, C., Szczerbicki, E. (2008) Decisional DNA and the smart knowledge management system: A process of transforming information into knowledge. In Techniques and tool for the design and implementation of enterprise information systems, ed. A. Gunasekaran, 149–175. New York: IGI Global
- [4] de Oliveira, C. S., Sanin, C., & Szczerbicki, E. (2019). Towards Knowledge Formalization and Sharing in a Cognitive Vision Platform for Hazard Control (CVP-HC). In Asian Conference on Intelligent Information and Database Systems (pp. 53-61). Springer, Cham.
- [5] Sanin, C., Toro, C., Haoxi, Z., Sanchez, E., Szczerbicki, E., Carrasco, E., Mancilla-Amaya, L. (2012). Decisional DNA: A multi-technology shareable knowledge structure for decisional experience. *Neurocomputing*, 88, 42-53.
- [6] C. Sanin, E. Szczerbicki (2009) Experience-based Knowledge Representation SOEKS. *Cybernet Sys.* 40(2), 99-122.
- [7] de Oliveira C.S., Sanin C., Szczerbicki E. (2020) Image Representation for Cognitive Systems using SOEKS and DDNA: A case study for PPE compliance, In: Nguyen N., Hoang D., Hong TP., Pham H., Trawiński B. (eds) Intelligent Information and Database Systems. ACIIIS 2020. Lecture Notes in Artificial Intelligence, <https://doi.org/10.1007/978-3-030-41964-6>
- [8] Szczerbicki E., Sanin, C. (2020) Knowledge Management and Engineering with Decisional DNA, Springer-Verlag <https://doi.org/10.1007/978-3-030-39601-5>.
- [9] https://www.java.com/en/download/help/java_6.html (acceded 01.04.2020)
- [10] Sanin, C., Szczerbicki, E. (2009) Experience-Based Knowledge Representation SOEKS. *Cybernetics and Systems*. Vol. 40(2)
- [11] Szczerbicki, E. NT Nguyen, NT. (2009) Applied Intelligent Systems, *Cybernetics and Systems*: Vol. 40, No 2
- [12] Sanin, C., Mancilla-Amaya, L., Szczerbicki, E., CayfordHowell, P (2009) Application of a Multi-domain Knowledge Structure: The Decisional DNA. Intelligent Systems for Knowledge Management, N. T. Nguyen, E. Szczerbicki: Springer Berlin / Heidelberg, Vol. 252
- [13] Kucharski, B., Szczerbicki, E. (2009) Experience database based on a workflow class system, *Foundations of Control and Management Science*, No 12
- [14] Zhang H., Sanin C., Szczerbicki, E. (2010) Decisional DNA-based embedded systems: A new perspective, *Systems Science*, Vol. 36
- [15] Mancilla-Amaya, L., Szczerbicki, E. Sanin, C. (2013) A proposal for a knowledge market based on quantity and quality of knowledge. *Cybernetics and Systems*. 44(2-3)
- [16] Kucharski, B., Szczerbicki, E. (2011) An approach to smart experience management, *Cybernetics and Systems*. Vol. 42.
- [17] Jabrouni, H. B., Kamsu-Foguem, Geneste, L., Vaysse, C. (2011) Continuous improvement through knowledge-guided analysis in experience feedback. *Engineering Applications of Artificial Intelligence* 24(8)
- [18] Zhang, H., Sanin, C., Szczerbicki, E.: (2013). Implementing fuzzy logic to generate user profile in decisional DNA television: The concept and initial case study. *Cybernetics and Systems* 44(2-3)
- [19] Toro, C., Sanchez, E., Carrasco, E., L. Mancilla-Amaya, L., Sanin, C., Szczerbicki, E., Graña, M., Bonachela, P., Parra, C., Bueno, G. (2013) Using set of experience knowledge structure to extend a rule set of clinical decision support system for Alzheimer's disease diagnosis. *Cybernetics and Systems* 43(2)

- [20] Shafiq, S. I., Sanin, C., Szczerbicki, E., Toro, C.: (2016). Virtual engineering factory: Creating experience base for industry 4.0. *Cybernetics and Systems* 47(1-2): 32–47
- [21] Waris M M, Sanin, C., Szczerbicki, E. (2019) Establishing Intelligent Enterprise through Community of Practice for Product Innovation, *Journal of Intelligent and Fuzzy Systems*, <http://dx.doi.org/10.3233/JIFS-179329>
- [22] Shafiq S.I., Sanin C., Carlos Toro, Edward Szczerbicki: (2016) Virtual Engineering Process (VEP): A knowledge representation approach for building bio-inspired distributed manufacturing DNA, *International Journal of Production Research*, DOI: 10.1080/00207543.2015.1125545
- [23] Sanin C, Leonardo Mancilla-Amaya, Zhang H., E. Szczerbicki: (2012) Decisional DNA: the Concept and its Implementation Platforms, *Cybernetics and Systems: An International Journal*, Vol 43, No 2, pp 67-80.
- [24] Thamiris de Souza Alves, de Oliveira C.S., Sanin C., Szczerbicki E. (2018), From Knowledge-based Vision Systems to Cognitive Vision Systems: A Review, Proceedings of Knowledge-Based Intelligent Information and Engineering Systems 22nd International Conference KES 2018, in Advances in Knowledge-Based and Intelligent Information and Engineering Systems: Robert J. Howlett, Lakhmi C. Jain (Eds.), Belgrade, Sep 2018, Elsevier Procedia Computer Science, <https://doi.org/10.1016/j.procs.2018.08.077>
- [25] Cesar Sanin and Edward Szczerbicki (2006) Similarity metrics for set of experience knowledge structure, Lecture Notes in Artificial Intelligence Proceedings of Knowledge-Based Intelligent Information and Engineering Systems 10th International Conference KES 2006, Rajiv Khosla Robert J. Howlett Lakhmi C. Jain (Eds.), UK, October 9-12, Springer-Verlag Berlin Heidelberg, pp 663-670.
- [26] C. Sanin and E Szczerbicki (2006) Developing Heterogeneous Similarity Measure for Knowledge Administration, *Cybernetics and Systems: An International Journal*, Vol. 37, pp 553-566.
- [27] Fabrikant SI, Buttenfield BP (2001) Formalizing Semantic Spaces for Information Access. *Annals of the Association of American Geographers* 91(2):263-280