Set of Experience Knowledge Structure (SOEKS) and Decisional DNA (DDNA) - A Review

A B M Mehedi Hasan[1]
Australian Institute of Higher Education
NSW, Australia
m.hasan@aih.nsw.edu.au

Mohammad Nafiz Ishtiaque Mahee [2]
BRAC University
Dhaka, Bangladesh
md.nafiz.ishtiaque.mahee@g.bracu.ac.bd

Cesar Sanin [3]
Australian Institute of Higher Education
NSW, Australia
c.sanin@aih.nsw.edu.au

Abstract—The concept of SOEKS and DDNA is to capture, store, organise, and re-use formal decisions in a knowledge-explicit form to help in decision-making. In this study, we review past works and advancements in the concepts of Decisional DNA (DDNA) and Set of Experience Knowledge Structure (SOEKS) since the birth of the original concept. Firstly, the original concept of SOEKS and DDNA, a comparison with human DNA and the construction of DDNA are discussed. In the second part, advancements of DDNA are investigated in chronological order. Lastly, the application and limitation of DDNA are discussed. Finally, the possible future advancements of DDNA are suggested.

Keywords— ***Set of Experience Knowledge Structure (SOEKS), Decisional DNA (DDNA), Knowledge Engineering, Evolutionary Algorithms (EA), Genetic Algorithms (GA), Virtual Engineering Object (VEO), Virtual Engineering Process (VEP), Industry 4.0, Internet of Things (IoT).***

I. Introduction

As we are heading towards the future with automation, we are generating more data than ever. Many of these data is generated on formal decision events and knowledge in the form of experience is, in many cases, overlooked or wasted. Such vast amount of data and knowledge experience requires proper collection, administration, and reuse. This is where the concept of Decisional DNA (DDNA) comes in. With the help of Set of Experience Knowledge Structure (SOEKS), it can both manage data in a systematic way, and be used for prediction based on previous decisional experiences. As it is still early days, our review tells us that there are some further opportunities for implementation and improvement of DDNA.

II. Literature Review

A. Concepts of SOEKS and DDNA

Concepts of "Knowledge Engineering" arrived from the necessity of a more organized way of knowledge and experience management. Noble (1998) suggested knowledge engineering as a specific discipline which focused on solving complex problem by virtue of merging knowledge into computer system. Sanin et al (2012) identified human intelligence capabilities such as learning, reasoning, and predicting as key aspects of knowledge engineering. "The only source of knowledge is experience" (Albert Einstein). According to Sanin and Szczerbicki (2009), multiple real-life applications can make decisions or support decision in a structured way which are called formal decision events. These formal decision events are commonly ignored, unexploited, and not stored in any process. This is where the concept of DDNA comes in with SOEKS (or SOE for short). Figure: 1 and Figure: 2 shows visual Decisional DNA and SOEKS respectively. These knowledge structures are capable of capturing previous formal decisions in a knowledge-explicit form (Sanin et al., 2012). Sanin also recommended to store past and present decisional data which turns into decisional fingerprints that can be applied to revamp the user's decisional experience.

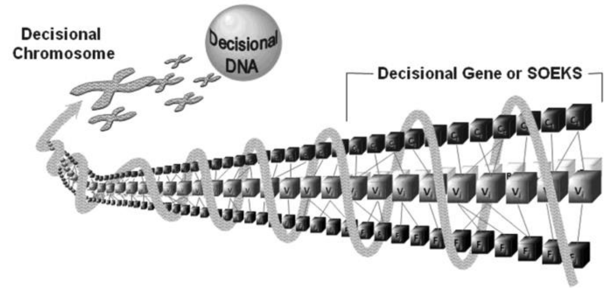

Figure 1: SOEKS and Decisional DNA (Sanin et al., 2012)

DDNA can be applied in several different technologies including common programming languages, markup languages, ontologies, software agents, and embedded systems (Sanin, 2012). Sanin (2012) emphasized some basic concepts to understands the DDNA concept in a proper manner. Initially, Sanin (2012) concentrated knowledge, more specifically previous experience, which worked while the decision-making process is executed. After that the authors talked about SOEKS as a more efficient and precise way of storing and representing formal decision events. Sanin and Szczerbicki (2009) defined 4 components which comprise SOEKS, they are: variables, functions, constraints, and rules.

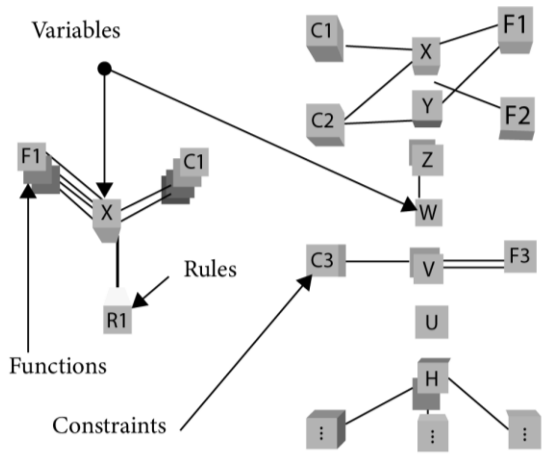

Figure 2: SOEKS (Sanin et al., 2012)

The initial part of the SOE is made up of variables that describe the decision-making process. Variables are connected through functions, the second part of SOEKS, which defines the relations among variables. The third element of SOEKS is constraints, which are restrictions on what is possible in the given system. Lastly, rules specify the actions relevant to the condition or circumstances. According to Sanin (2012), to perform in an optimal way, multiple SOEKS need to be captured from daily experiences in order to make the system grow in knowledge.

B. Biological DNA and brain functions

Szczerbicki and Sanin (2020) compared the human body with a robust information management system. The success of the DNA structure demonstrated by the persistence of knowledge throughout subsequent generations in nature has led the experts to correlate DNA with a data structure. DNA allowed humans to store their experience and knowledge through multiple generations to survive and improve over time. Furthermore, the brain is the most potent database and processor as it can store and process experiences as knowledge. DNA and the brain combined to create a perfect mechanism for humans to process and assemble experience that can be used both for survival and improvement in humans. DNA is a type of nucleic acid in all organisms and is the basis for inheritance. It is formed with two strands around a helix axis, creating a helical spiral-like shape. Both strands consist of a different combination of four unique nucleotides: Adenine (A), Thymine (T), Guanine (G) and Cytosine (C). Each human is unique from one another due to the different combinations of these four nucleotides. A gene is a section of the DNA molecule that directs the function of a specific part of an organism and gives a direction under different circumstances. Chromosomes consist of a pair of genes, and several chromosomes combine to form the complete genetic code of a single person. The human brain, on the contrary, receives signals from the human body and interprets them to create a proper reaction. Psychologist George Kelly suggested a theory of "psychological space" which does not exist beforehand but is instead created while going through decision-making scenarios. Kelly further explained it as a multivariate system of intersects and concepts. Based on these concepts, Szczerbicki and Sanin (2020) proposed psychological space of a person contains previous decision events. In the case of a new decision-making event, an experienced person makes their current decisions based on these previous interactions that suited them better.

C. Digital archnitecture and construction of DNA

Sanin et al. (2012) suggested that past decision-making experiences are often overlooked and not adequately maintained. Due to differences in technologies between generations or lack of a proper knowledge management system paves the way for loss of decisional experience. Sanin and others identified two key reasons behind this circumstance. Firstly, he recognized the inadequate knowledge structure to store formal decision events. Secondly, the technological challenges to maintaining such experiences. The authors further introduced some solutions. Initially, they offered to implement a knowledge structure like DDNA and SOEKS to maintain the knowledge appropriately. After that, they suggested a mechanism to apply various technologies to gather experiences. Finally, they advocated for an automated process that can give solutions to current scenarios based on previous knowledge.

In modern times we need better ways to gain insight into data as analysing is expensive and lacklustre. There can be multiple ways to equate different data objects. Bringing efficiency in searching for patterns finding similarities between two data objects can provide better results. This is a crucial concept not only in data mining, but also in knowledge discovery. Moreover, this process can create a ranking system that would provide the best matching objects, i.e., previous experiences to help in solving a current decision query. Similarities can be measured in numerous ways. Depending on the process, the similarity may vary from an object. However, various similarity matrices of the same type can be applied to the same set of data objects. So, choosing which metric to use is vital, considering our output. A systematic approach for similarity metric is multidimensional scaling, where a geometric approach is taken to plot the objects in continuous dimensions. Distance between objects where the closest plotted object is considered the most similar. The critical flaw in this approach becomes visible when we must plot objects with multiple qualitative attributes. To bypass this issue, researchers suggested pre-arranging qualitative attributes as binary variables. Sanin et al. (2012) suggested that Euclidian and Hamming matrices, part of the Minkowskian family distance matrices, can take two attribute vectors s_i and s_j and calculates the distance "d" in the following manner:

$$d_{ij} = \left[\sum_{k} w_k \left|s_{ik} - s_{ij}\right|^{r}\right]^{\frac{1}{r}}$$

Here,
w_k = given weight to the k^{th} attribute.
r = parameter that determines which of the family of metrics is used.

Besides this, event sequence techniques have been used in some cases. Also, other special techniques like additive trees, additive clustering, information content, mutual information, dice coefficient, cosine coefficient, and feature contrast model could be used.

D. SOEKS and DDNA in research

The management of knowledge challenges us when it comes to the ways of organizing the knowledge. The major obstacle to achieving this goal is the lack of storing isolated solutions when problems are experienced. The idea is simple; learn a new problem, solve the problem, store solutions, organize knowledge, and re-use knowledge for decision-making purpose. SOEKS and DDNA concept open a door to see the problem-solving world in a new form. Sanin and Szczerbicki (2005) first proposed a knowledge structure to store and re-use experiences to make decision-making easier. They called it 'The Set of Experience Knowledge Structure' or SOEKS. We noticed an appreciable amount of research on SOEKS and DDNA. Shafiq et al. (2014) discussed the past, present, and future of DDNA and SOEKS and summarized in a tabular form SOEKS and DDNA applications by different authors. In this literature review, we explored the major development of SOEKS and DDNA and its state of the art. Relevant below information recorded in Table 1.

Table 1: Development of SOEKS and DDNA

Development of DDNA and/or SOEKS	**Author and Year**

The authors proposed the set of experience knowledge structure to support in recording past experiences leading to an easier decision-making process. According to the authors, decisions taken in the past can be recorded and future decision-making can be made easy by capturing knowledge in the shape of SOEKS. According to our observation, this study has led further investigations on DDNA enabling knowledge management and smart decision-making ideas by many authors.	Szczerbicki and Sanin (2005a)
Besides proposing the idea of SOEKS and DDNA, Sanin and Szczerbibcki realised that the portability of set of experience knowledge structure is crucial to enable compatibility with diverse systems. They chose XML (Extensible Markup Language) and converted SOEKS into XML to transform DDNA into XML-based knowledge structure.	Szczerbicki and Sanin (2005b) Szczerbicki and Sanin (2007a)
Sanin and Szczerbicki (2006a) showed how SOEKS is implemented in the Knowledge Supply Chain System (KSCS). Knowledge management can be a challenging task due to organisation complexity and quality of knowledge. Mancilla-Amaya et al. (2012) determined the quality of knowledge based on some attributes; some of the attributes are: relevance, completeness, accuracy, timeliness, and objectivity. Sanin and Szczerbicki (2004) proposed this conceptual model to support knowledge management problems which is the knowledge supply chain system (KSCS), supported by SOEKS. Incoming SOEKS can be classified and comparable before proceeding further in a target system. Comparison and classification of SOEKS would be helpful minimising errors occurring while feeding external systems. Sanin and Szczerbicki (2006b) developed heterogenous similarity metrices to make formal decision making more acceptable in knowledge management and in multi-platform/technology use.	Sanin and Szczerbicki (2006a), Sanin and Szczerbicki (2006b)
According to the Szczerbicki and Sanin (2007b), sometimes there are different heterogenous or diversified sets of experience as output of a unique formal decision event. They realized the necessity of a homogeneous form of the set of experience collecting the formal decision event and adding compatibility among various platforms offering intelligent systems. Szczerbicki and Sanin (2007c) presented a Java class ontology implementation to derive benefits from experiential knowledge that can be used in different industries or domains. The Java class with an ontology implementation system is supported by a combined set SOEKS, DDNA, and SOUPA. According to Chen et al. (2004), SOUPA is a shared standard ontology to support ubiquitous and pervasive computing systems. Szczerbicki and Sanin extended SOUPA with SOEKS to enhance DDNA which is aligned with the ontology of universal applications or systems.	Szczerbicki and Sanin (2007b), Szczerbicki and Sanin (2007c), Szczerbicki (2007)
Sanin and Szczerbicki (2007d) chose a meta-heuristic technique to find an optimal set of experience from homogenization and mixture of varous sets of experience knowledge structure. Based on the recommendation by Zitzler et al. (2000) and Fonseca and Fleming (1995), Sanin and Szczerbicki were convinced that Evolutionary Algorithms (EAs) are a good fit for multi-objective optimization (MOO). A Genetic Algorithm (GA) was selected because biological chromosomes can be interpreted by GA. The authors also found a disadvantage of Genetic Algorithms. Because of the heuristic nature of GAs, optimal solution is not guaranteed. Sanin and Szczerbicki also explored and 'Strength Pareto Evolutionary Algorithm' (SPEA) because this SPEA outperformed other four multi-objective evolution algorithms tested by Zitzler & Thiele (1999).	Szczerbicki and Sanin (2007d)
Previously, Szczerbicki and Sanin extended SOUPA ontology with SOEKS. Toro et al. (2008) proposed the concept of 'reflexive ontologies' as a framework. With	Toro et al. (2008) Sanin et al. (2008)

this approach, any existing ontology can be extended. The authors added a case study of testing SOEKS with this framework. Creating trust in decision making with DDNA is crucial. Sanin et al. (2008) combined decisional DNA, reflexive ontologies, and security technologies and proposed 'decisional trust'. This was proposed to offer trustable decisions by extending the use of DDNA and reflexive ontologies.	
Sanin et al. (2012) refreshed the idea of SEOKS and DDNA from previous studies and showed four types of application potentials of DDNA: XML-based DDNA Knowledge Structure, Ontology based DDNA Knowledge Structure, DDNA for Software Agents Technology, and DDNA-Based Embedded Systems.	Sanin et al. (2012)
Cyber physical systems are a combination of interactive networks of physical and other computer components (Griffor et al., 2017). Internet of Things (IoT) can be defined as an interconnected network of objects. Sanin et al. (2019) shared case studies on SOEKS and DDNA can be a knowledge representation component for Internet of Things (IoT) and Cyber Physical Systems. The authors presented the following architecture for all case studies: DDNA-based IoT architecture, computer integrated manufacturing, hazard control system, and smart innovation engineering system (SIE).	Sanin et al. (2019)
Shafiq et al. (2021) demonstrated DDNA-based machine monitoring to perform overall maintenance in industry 4.0 framework. According to the authors, with virtual engineering object (VEO) (Shafiq et al., 2015), virtual engineering process (VEP) (Shafiq et al., 2015) and virtual engineering factory (VEF) (Shafiq et al., 2016), the manufacturing footprints can be captured. They stored formal decisions of VEO-based wear monitoring, VEO-based condition monitoring, and VEP-based quality prediction and monitoring into CSV (comma separated value) format. The data were read with the help of Java programming code and converted to SOEKS, followed by the creation of productive maintenance-DNA.	Shafiq et al. (2022)

III. Applications of SOEKS and DDNA

A. DDNA Based Embedded System

Knowledge based embedded systems are useful when they offer an efficient way of gathering, using, distributing, and re-using knowledge. According to Zhang et al. (2010a), sharing knowledge among various knowledge-based systems can be hectic, time consuming, and expensive when there are no standardised solutions. Cesar et al. (2012) suggests that DDNA is cross platform compatible, compact, and configurable which makes DDNA a good fit for the integration with embedded systems.

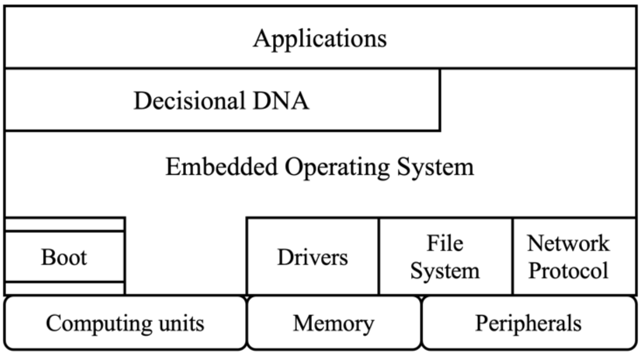

Figure 3: Architecture of decisional DNA-based embedded systems (Sanin et al., 2012)

B. Decisional DNA in Web Data Mining

Web data mining can be beneficial to website owners to track not only performance of their website, but also opens the door to investigate user insights with visualisations. This helps website owners to improve their business strategy. According to Wang et al. (2011), business decision making can be more efficient together with Decisional DNA and data mining. The author proposed a new way of web data mining (web usage or content mining) with Decisional DNA.

C. Decisional DNA in Robotics

Storing knowledge or experiences in a structured way and using stored experiences to improve decision making is the core benefit of Decisional DNA. Robots are being deployed in different conditions. An automated smart manufacturing plant can be a good example to relate DDNA. If robots can learn from the set of experiences, re-use knowledge or experience, errors can be minimised. Zhang et al. (2010b) demonstrated an approach on how robots can use Decisional DNA to capture, store and re-use knowledge.

IV. Limitations of DDNA Supported Information Systems

Technological advancements never stop. Humans learn from experience and advance technologies to make their lives easier. Now-a-days, we can see advancement of computing, hardware, software, cloud services, blockchain and what not. Ongoing research of DDNA/SOEKS and maintaining compatibility with different systems are crucial. Further research on the limitations of DDNA/SOEKS-based information systems is pending but, it can be stated that integrating or mixing machine learning (ML) with DDNA knowledge structure may bring more applications ideas.

V. Future Advancements of SOEKS and DDNA

In this modern day and age, we are constantly facing decision making events, and among them, a big part of them is being taken by not humans but rather machines. These events generate numerous decisional experiences. If implemented, DDNA could provide immense success. As we move towards automation gradually, we are focusing on executing machine learning algorithms on multiple occasions. Primarily, image processing is being used in our day-to-day life more than we are aware of. In these cases, we are processing a considerable amount of data that could be better handled with the DDNA. Also, with the help of natural language processing, we are creating algorithms witch which computers can continue conversations like humans. These algorithms learn from past conversations and take decisions as the current conversation progresses. Even here, we can see a situation of managing a massive amount of data and the importance of decisional experience. DDNA could be added to popular language libraries to be helpful in artificial intelligence. Furthermore, companies with massive data use query languages and other data management services to maintain their substantial data repositories properly. These enterprises regularly take huge decisions based on their data and past circumstances. DDNA can be implemented in query language as well. While constructing DDNA in such affairs Sanin (2012) suggested keeping in mind to maintain search capabilities by keywords, permitting extraction of relevant elements, preserving easy maintenance of knowledge, and keeping the structure of DDNA intact. DDNA and SOEKS can be integrated with search engines. As DDNA can provide results from decisional experiences thus it can produce results based on the user's criteria or specific needs in an efficient way.

VI. Conclusion

The necessity to properly oversee massive amounts of data is increasing every moment. DDNA can prove vital as it can manage and give predictions while considering past decisional experience, all while maintaining its proper structure. As technology progresses, we can implement DDNA along with SOEKS in multiple scenarios, which can help us to administrate a large amount of data while having the benefits of searching and predicting as well.

References

[1] Chen, H., Perich, F., Finin, T., & Joshi, A. (2004, 26-26 Aug. 2004). SOUPA: standard ontology for ubiquitous and pervasive applications. The First Annual International Conference on Mobile and Ubiquitous Systems: Networking and Services, 2004. MOBIQUITOUS 2004.,

[2] Fonseca, C. M., & Fleming, P. J. (1995). An Overview of Evolutionary Algorithms in Multiobjective Optimization. Evolutionary Computation, 3(1), 1-16. https://doi.org/10.1162/evco.1995.3.1.1

[3] Griffor, E. R., Greer, C., Wollman, D. A., & Burns, M. J. (2017). Framework for cyber-physical systems: Volume 1, overview.

[4] Noble, D. (1998). Distributed situation assessment. In Proc. FUSION (Vol. 98, pp. 478-485).

[5] Sanin, C., Mancilla-Amaya, L., Haoxi, Z., & Szczerbicki, E. (2012). Decisional DNA: The concept and its implementation platforms. Cybernetics and Systems, 43(2), 67-80.

[6] Sanin, C., & Szczerbicki, E. (2004). Knowledge supply chain system: a conceptual model.

[7] Sanin, C., & Szczerbicki, E. (2005a). Set of experience: a knowledge structure for formal decision events. Foundations of Control and Management Sciences, No. 3, 95-113.

[8] Sanin, Cesar, & Szczerbicki, E. (2005b). Using XML for Implementing Set of Experience Knowledge Structure BT - Knowledge-Based Intelligent Information and Engineering Systems (R. Khosla, R. J. Howlett, & L. C. Jain (eds.); pp. 946–952). Springer Berlin Heidelberg.

[9] Sanin, Cesar, & Szczerbicki, E. (2006a). Using set of experience in the process of transforming information into knowledge. *International Journal of Enterprise Information Systems (IJEIS)*, *2*(2), 45–62.

[10] Sanin, Cesar, & Szczerbicki, E. (2006b). DEVELOPING HETEROGENEOUS SIMILARITY METRICS FOR KNOWLEDGE ADMINISTRATION. *Cybernetics and Systems*, *37*(6), 553–565. https://doi.org/10.1080/01969720600734495

[11] Sanin, C., & Szczerbicki, E. (2007a). EXTENDING SET OF EXPERIENCE KNOWLEDGE STRUCTURE INTO A TRANSPORTABLE LANGUAGE eXTENSIBLE MARKUP LANGUAGE. *Cybernetics and Systems*, *37*(2–3), 97–117. https://doi.org/10.1080/01969720500425046

[12] Sanin, C., & Szczerbicki, E. (2007b). DISSIMILAR SETS OF EXPERIENCE KNOWLEDGE STRUCTURE: A NEGOTIATION PROCESS FOR DECISIONAL DNA. Cybernetics and Systems, 38(5-6), 455-473. https://doi.org/10.1080/01969720701344210

[13] Sanin, C., & Szczerbicki, E. (2007c). TOWARDS THE CONSTRUCTION OF DECISIONAL DNA: A SET OF EXPERIENCE KNOWLEDGE STRUCTURE JAVA CLASS WITHIN AN ONTOLOGY SYSTEM. Cybernetics and Systems, 38(8), 859-878. https://doi.org/10.1080/01969720701601189

[14] Sanin, C., & Szczerbicki, E. (2007d). GENETIC ALGORITHMS FOR DECISIONAL DNA: SOLVING SETS OF EXPERIENCE KNOWLEDGE STRUCTURE. Cybernetics and Systems, 38(5-6), 475-494. https://doi.org/10.1080/01969720701344269

[15] Szczerbicki, E. (2007). EDITORIAL: KNOWLEDGE MANAGEMENT AND ONTOLOGIES—PART II. Cybernetics and Systems, 38(8), 755-757. https://doi.org/10.1080/01969720701601015

[16] Sanín, C., Szczerbicki, E., & Toro, C. (2008). COMBINING TECHNOLOGIES TO ACHIEVE DECISIONAL TRUST. *Cybernetics and Systems*, *39*(7), 743–752. https://doi.org/10.1080/01969720802257972

[17] Shafiq, S. I., Sanin, C., Szczerbicki, E., & Toro, C. (2015). Virtual Engineering Object / Virtual Engineering Process: A specialized form of Cyber Physical System for Industrie 4.0. Procedia Computer Science, 60, 1146-1155. https://doi.org/https://doi.org/10.1016/j.procs.2015.08.166

[18] 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. https://doi.org/10.1080/01969722.2016.1128762

[19] Sanin, C., Haoxi, Z., Shafiq, I., Waris, M. M., Silva de Oliveira, C., & Szczerbicki, E. (2019). Experience based knowledge representation for Internet of Things and Cyber Physical Systems with case studies. Future Generation Computer Systems, 92, 604-616. https://doi.org/https://doi.org/10.1016/j.future.2018.01.062

[20] Shafiq, S. I., Sanin, C., & Szczerbicki, E. (2022). Decisional DNA (DDNA) Based Machine Monitoring and Total Productive Maintenance in Industry 4.0 Framework. Cybernetics and Systems, 53(5), 510-519. https://doi.org/10.1080/01969722.2021.2018549

[21] Toro, C., Sanín, C., Szczerbicki, E., & Posada, J. (2008). REFLEXIVE ONTOLOGIES: ENHANCING ONTOLOGIES WITH SELF-CONTAINED QUERIES. *Cybernetics and Systems*, *39*(2), 171–189. https://doi.org/10.1080/01969720701853467

[22] Wang, P., Sanin, C., & Szczerbicki, E. (2011). *Application of Decisional DNA in Web Data Mining BT - Knowlege-Based and Intelligent Information and Engineering Systems* (A. König, A. Dengel, K. Hinkelmann, K. Kise, R. J. Howlett, & L. C. Jain (eds.); pp. 631–639). Springer Berlin Heidelberg.

[23] Zhang, H., Sanin, C., & Szczerbicki, E. (2010a). Decisional DNA-based embedded systems: A new perspective. Systems Science, Vol. 36, no 1, 21-26.

[24] Zhang, H., Sanin, C., & Szczerbicki, E. (2010b). *Decisional DNA Applied to Robotics BT - Knowledge-Based and Intelligent*

Information and Engineering Systems (R. Setchi, I. Jordanov, R. J. Howlett, & L. C. Jain (eds.); pp. 563–570). Springer Berlin Heidelberg.

[25] Sanin, C., & Szczerbicki, E. (2009). Experience-based knowledge representation: SOEKS. Cybernetics and Systems: an international journal, 40(2), 99-122.

[26] Szczerbicki, E., & Sanin, C. (Eds.). (2020). Knowledge management and engineering with decisional DNA. Springer International Publishing.

[27] Shafiq, S. I., Sanín, C., & Szczerbicki, E. (2014). Set of Experience Knowledge Structure (SOEKS) and Decisional DNA (DDNA): Past, Present and Future. Cybernetics and Systems, 45(2), 200-215. https://doi.org/10.1080/01969722.2014.874830

[28] Zitzler, E., & Thiele, L. (1999). Multiobjective evolutionary algorithms: a comparative case study and the strength Pareto approach. IEEE Transactions on Evolutionary Computation, 3(4), 257-271. https://doi.org/10.1109/4235.797969

[29] Zitzler, E., Deb, K., & Thiele, L. (2000). Comparison of Multiobjective Evolutionary Algorithms: Empirical Results. Evolutionary Computation, 8(2), 173-195. https://doi.org/10.1162/106365600568202