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The Enterprise DNA: Static and Dynamic Digital Representation of Organizations

Roman Trotsyuk, Vítor Santos

Abstract*: *The contemporary business environment become more complex and fast changing. The complex interactions and enterprise life cycle reminds the life of s species in the nature and , thus ,the mimic of biological entities can be applied as a modelling tool for better understanding how company operates and what makes it s successful. The broad purpose of this article is to propos e a foundation for applying Artificial Life s simulations for business analyse. Artificial Life is a concept that allow to mimic biological evolution and behaviour of living creatures for modelling complex systems , forming specific environment with interacting and evolving agents. The main goal of this paper is the research and suggestion of such characteristics and their representation, which will constitute Enterprise DNA. As the foundation of important company's features, the Enterprise Architecture concept was applied. The Zach man Enterprise Architecture framework used as a base is of enterprise representation. Accordingly, the artefacts for phenotype representation are proposed and then, their digital XML representation found. The DNA digital representation model (genotype) for artefacts is proposed. This representation can be used by means of Genetic Algorithm for further implementation of Artificial Life's simulation on real company's data.

Keywords* : *Artificial Life, A Life, Corporate DNA, Competitive Strategy, Enterprise Architecture, Enterprise DNA, Evolutionary Algorithms, Genetic Algorithms, Genetic Algorithm Representation

I. INTRODUCTION

The main idea is to mimic company's behaviour by means of biologically inspired simulation models. Such models usually called Artificial Life simulation (1) by analogy with real life and was developed for modelling complex, evolutional systems. The Artificial Life (A Life) conception implies modelling of research entities by means of Genetic Algorithms (2), which can model every individual within specific population, their interaction, mating, mutations and adaptation to the environment. The Enterprise Architecture frameworks are considering as a basement for projecting the Enterprise's DNA structure.

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* Correspondence Author
Roman Trotsyuk*, 1NOVA Information Management School, Lisbon, Portugal
Vítor Santos, 1NOVA Information Management School, Lisbon, Portugal

The problem is the modelling of the enterprises and their interactions by analogy with living species for better understanding how they behave, which components make them successful. This kind of modelling is called Artificial Life simulation and usually implemented by means of evolutionary algorithms. Genetic algorithms implementation implies three main steps:

- Development of genotype representation of the individual (representation problem)
- Design of fitness function, that will evaluate successfulness of the individual
- Simulation by means of Artificial Life algorithm

Thus, the representation problem is the first on the way to implement evolutionary competition model of the enterprises and, thus, is the objective of this research. Other steps considered as a suggestion for further development of the topic. As far as we are aware, there were no similar researches propose before. The novelty is in the applying Artificial Life simulations to the business competitiveness. Another innovation proposed are the representation of the enterprise by its DNA and use for that purpose the Enterprise Architecture framework.

Each company existing mimic living organisms with their DNA – specific structure and properties sets, behaviour, reactions and relevance to the environment. Thus, the idea of application of A life simulation to the business competitiveness looks promising.

This work is theoretical one and its evaluation is a challenge. For this purpose, experts in evolutionary algorithms should be attracted for validation of developed model. Further works will show in practice value of ideas proposed.

The goal of this work is to propose the representation of Enterprise's DNA that can be used for further modelling of organizations by means of Artificial Life simulation. This representation must cover main aspects of the company and reflex its constitution.

Thus, the research objective is the design of Enterprise's DNA. As foundation for individual representation with Enterprise Architecture frameworks are considered, which are used for description of company's business architecture. The idea is new regarding goals stated, nonetheless seems very promising to use this approach for achieving better results in understanding how business operates, what makes it better and what "Genes" lead to success .

II. THEORETICAL FRAME WORK

2.1 Enterprises

Companies can be seen from points of view: internal and external. From external viewpoint there are number of classifications of enterprises that discern them by different typology. Belonging to each class or group carry some specific characteristic. From internal point of view companies differ by their Enterprise Architecture.

There are number of enterprise classifications that examine companies from different sides and serving for specific purposes. The 10 guidelines for the empirical classification of organizations were proposed by Bill McKinley (3). In further paper he proposed characters for organizations typology based on work (4) implies finding similarities and differences among organization applying biological taxonomy methods (5). Other work (6) discusses empirical, theoretical and evolutionary perspectives of organizations typology, hierarchical taxonomy and defines methodological consistency of classification systems. United Nations developed its "International Standard Industrial Classification of All Economic Activities" (7). European Commission agency Euro stat provides own standard "NACE Rev. 2 Statistical classification of economic activities in the European Community" (8). In 1999, Standard & Poor's and MSCI/Barras jointly developed the Global Industry Classification Standard (GICS) (9) to establish a global standard for categorizing companies into sectors and industries.

Enterprise architecture is positioned within the context of managing the enterprise. It offers a holistic perspective of the current and future operations, and on the actions that should be taken to achieve the company's goals (10). Thus, the Enterprise Architecture describes company from internal point of view and includes properties specific to the company which can be considered as Genes of the organization. Set of characteristics, defined by Enterprise Architecture constitutes the DNA of the company.

There are many frameworks developed for Enterprise Architecture modelling. Today, four methods are dominant: Zach man's structure for enterprise architecture, TOGAF (The Open Group Architecture Framework), Federal Organization Architecture (FEA) and Methodology Gartner (formerly called Meta Framework).

Significant contribution to the development of the concept of the enterprise architecture was made by J. Zach man (11). Since 1987, when it was proposed the first version of this model, extended subsequently in the later works (12), (13). For purposes of this paper Zach man framework is considered as it is widely used, simple and flexible tool.

All six aspects of the Zach man enterprise framework can be represented with specific for each column artefacts. Some of possible artefacts but without specific standard recommendations were shown by Zach man in his framework (13).

For purposes of this work we will consider Conceptual perspective of Zach man framework. The justification of this choice is following: Scope level is to general and some enterprises can be described equally though there are different that we can see only on following layers. Logical and more detail perspective are too specific and can even distinguish in the same company. Moreover, very detailed description can make representation very complex, company specific and thus, become incomparable model.

More specifically artefacts for implementation of Zach man framework were proposed later (14). For the Conceptual level there were considered following standards: WHAT–Entity-Relationship Model (ERM), HOW – Integrated Definition for Process Description Capture Method (IDEF3), WHERE – Graph, WHO – Org Chart, WHEN - Gantt chart, WHY – Structured English. We can represent our what (Data) perspective of Zach man Framework with Entity-Relationship (ER) diagrams (14). Entity-relationship concept was applied for data modelling (15). For the purposes of this paper we have to consider not only the representation designed for human but one consigned for computers. For this W3C with Peter Chen as one of participants (16) proposed the XML format (15) for digital ER diagram representation. There were proposed several works for converting ER to XML (17), thus, we can make representation of our Data perspective that computer can treat.

The third perspective of Zach man Framework is Where (Network). It represents geographical and logistic structure of enterprise and its parts (13) and (21). For Conceptual aspect (14) proposed Graph as a representation of company's logistic (supply chain) network. (22) Proposed The Supply Chain Modelling Language (SCML) based on XML standard for modelling odd logistic networks which can be used as the representation of network structure of the Enterprise.

The fourth perspective of Zach man Framework is who (People). It represents company's structure and functions performers, which can be grouped in many ways with different degree of responsibility, centralization, thus, forming managerial hierarchy (23). For Conceptual aspect (14) proposed Org Charts as representation, that is simple, straightforward and widely used by business entities. The Organization Chart usually have hierarchical structure and c an be represented in XML format (24), because both (Org Chart and XML) have hierarchical structure.

The fifth perspective of Zach man Framework is When (Time). It represents time of events significant for the operating of the company (12). The interconnected time events and project steps in Zach man framework can be represented as Gantt Charts (14). (25) showed XML Project Management Method (PMM) representation of Gantt Chart with PMXML (Project Management XML) format. (26) also proposed XML representation of schedules and Gantt Charts.

The last, sixth perspective of Zach man Framework is Why (Motivation). It represents goals of the company (12). Business goals framework was proposed by (27) as Balanced Scorecard which represent business goals connected and grouped by four perspectives: customer, finance, internal operations and development. (28) showed that BSC XML draft standards can be used for XML representation of company's goals - Balanced Scorecards.

2.2. Artificial Life and genetic algorithms

The phrase "Artificial Life", that became the name of the science was proposed by hristopher Langton (1).

Langton gave the definition of A Life as following: "Artificial lifes the study of artificial systems that exhibit behaviour characteristic of natural living systems. Thus, Artificial Life can be used as simulation environment to model and simulate behaviour of companies on the market, where organizations are considered as living organisms interacting with each other. For the purposes of this paper we consider the Artificial Live that can be modelled by means of Evolutionary (Genetic) Algorithms.

Genetic algorithms (GA) are stochastic, heuristic optimization methods, first proposed by John Holland in 1975 (2). They are based on the idea of evolution through natural selection. The advantage of a GA is that it finds approximate optimal solutions in a relatively short time (29). Thus, GA can be used as foundation for Artificial Life simulation.

For implementation of Genetic Algorithm, the DNA of the individual must be represented in digital and convenient way to make the solution of the problem possible.

III. METHODOLOGY

The aim of this paper is to create digital representation of Enterprise DNA which, strictly speaking, is the model for information system (artificial life simulation genetic algorithm), that, in turn, will simulate competitiveness of an Enterprises. For developing of new knowledge in Information Science the Design Science Research (DSR) discipline and framework was structured and developed (30), (31). This framework defines steps for development of new Information Systems Science artifacts. Using DSR framework we can classify proposed idea as an Invention (32). Following steps (see Table 1) were fulfilled and results obtained:

Table 1. Research steps.

Step	Results
Introduction	• Statement of the problem and research objectives • Are there other paper on this subject?
Literature Review	Finding similar works and previous researches related to study explaining: • Typology of enterprises • Enterprise Architecture frameworks • Zachman framework • Artefacts for the representation of Enterprise aspects • Concepts of Artificial Life and Genetic Algorithms
Method	Design Science Research method
Artifact Description	Digital representation of Enterprise DNA using XML standard
Evaluation	• Interview with GA domain experts
Discus s ion	• Analysis of the created Enterprise DNA representation • Explanation how it can be used • Understand the pros and cons
Conclusions	Conclusions on the proposed Artefacts and further development of the research topic

Proposed model is theoretical, so the problem of validation arises. As a solution of this problem the interviews with experts in evolutionary algorithms from academia were organized. For the review of work: a usage of proposed Enterprise Architecture Framework, discovered artifacts, their XML representation and the final Enterprise DNA model were invited following experts :

• Mauro Castelli, Assistant Professor at NOVA Information Management School, Doctor in
Computer Science - University of Milano Bifocal - Italy.

• Flávio L. Pinheiro, Invited Assistant Professor of Data Science at NOVA Information
Management School, Ph.D. in Physics – University of Minho.

The interviews were performed for receiving of the feedback on usefulness and quality of proposed model, research strategy and the assumptions for the improvement of the model. The three follow ing questions were asked:

1. Usefulness of having an Enterprise DNA model
2. Agreement with the adopted strategy to build the Enterprise DNA
3. Recommendations for improvement

IV. RESULTS AND DISCUSSION

In this part of the research the Enterprise DNA model is synthesized and discussion regarding results
conducted. The chromosome model based on assumptions such as use of enterprise typology, Zach man Enterprise Architecture Framework as the foundation and further perspective of Artificial Life simulation. Digital representation of DNA phenotype artifacts as XML representation is proposed that resulted in model of genome. Interview with the topic experts performed for validation and discussion of results, then improvement of the model and possible future works proposed.

4.1. Model of the DNA representation of a generic enterprises

The Owner's (Conceptual) view is assumed. Further, scientific papers which research XML representation of that artifacts were considered. Thus, we can build digital Enterprise's DNA representation, based in XML format. The Zach man framework has six aspects of the Enterprise, which describe most of company's behavioural and structural properties. These aspects of Zach man Framework with proposed artifacts and their XML representation are shown Table .

Table 2. Proposed artefacts and XML representation.

Aspect	Artifact	XML Representation
Data	ER Diagram	XML format for ER diagram
Function	BPMN	XPDL
Network	Network Graph	SCML
People	Organizational Structure	XML format
Time	Gantt chart	PMXML (Project Management XML) format
Motivation	Balanced Score Card	BSC XML

Enterprise's DNA outline. Summarizing assumptions stated above the Enterprise DNA representation was synthesized. Proposed model consists of several sub genes based on Zach man framework artifacts and service information. For the simplicity and applicability of the model artifacts will be stored outside individual, to avoid redundancy, because genes can be duplicated among the simulation population. The outline of the proposed Enterprise's DNA representation is shown on the Figure 1

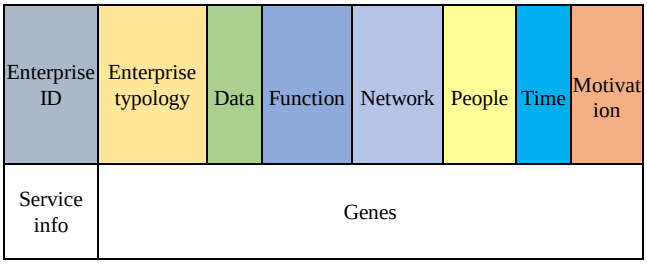

Figure 1. Outline of Enterprise's DNA representation.

The Enterprise ID section contains identification information of the Company. Other sections are sub genes of the DNA. Enterprise typology sub genes show different taxonomies that can characterize company. The following artefacts: Data, Function, Network, People, Time, Motivation describe Enterprise aspects regarding Zach man Framework.

The main assumption for each Enterprise's DNA section is a fixed length and structure, which is needed for simplifying of crossover operations. Thus, Individual's Gene can be matched with the same Gene of its mate. The length itself depends on researcher's decisions about acquired reference models and artefacts used. For example, if for enumerating of Function artifacts we use APQS process framework (33) or SCOR reference model (34) the length of sub gene "Function" must be set according utilized framework.

Enterprise's DNA structure. The Enterprise's DNA consists of service information (Enterprise's ID) and Genes (sub DNA), which in turn contain all necessary for executing Artificial Life algorithm information. Enterprise ID is service part of DNA which allotted for identification of specific Enterprise during simulation.

The XML representation of Enterprise DNA is textual and thus requires significant space in the computer memory. In the proposed model for the purpose of reducing the memory usage the subgenus are represented by reference ID which point to gene\subgenre specific dictionaries in which XML values of the artifacts are stored. Thus, for the genetic algorithm operations as initialization, crossover and mutation we used only one reference value instead of big XML text. For calculation of fitness function the XML value can be restored by "Subgenre value ref" reference.

4.2. Discussion

The interview answers provided by experts allow us to consider proposed Enterprise DNA model as valuable and useful for the goals of company's competition simulation by means of Artificial Life algorithms. The adopted strategy was discussed and approved and recommendations for improvement were given.

On the first question, asked to determine usefulness of having Enterprise's DNA model all experts gave positive feedback. This model is beneficial in the sense that it is different with respect to existing models that are commonly used for modelling of enterprise because with this model able to somehow capture the interaction between companies.

On the second question about agreement with the adopted strategy to build the Enterprise DNA also were given positive feedbacks with some remarks. Experts agreed with this kind of modelling and made remarks regarding which may require to add to this modelling strategy usage of external factors. It was pointed that any classifications used in Enterprise Typology gene can have very high correlation and it makes sense to use smaller set of subgenres – to reduce dimensionality

The last, third question was asked about recommendations for improvement. Interviewed experts provided few interesting suggestions regarding model improvement and running the artificial life simulation, which are:

- To include in the model other factors that are not specific to companies but are external to them:

some kind of political, economic, socio-cultural and technological (PEST) conditions;

- To consider not only simulation of competition of different companies on the same market, but also behaviour of similar companies in different markets, with various economic, geographic, political, etc. conditions;
- To reduce the complexity of the model when implement it because it has too many variables, very big subgenre set. Reduce the dimensions and number of variables, especially that can be correlated – similar typologies etc.;
- To consider necessity of Typology Gene because sometimes the classification is based on someone's subjectivity and not really represents the field.

Thus, considering the validation interview and answers of experts on questions asked we can conclude that proposed model is valuable and useful for research hers, consultants and managers by getting various insights on the company composition, evolution and strategy.

V. CONCLUSION

Since the Enterprise DNA representation and simulation topic is undeveloped there were few limitations that discussed below:

- The proposed model does not consider intangible company's assets as a brand, a culture etc.
- This model does not consider tangible assets of the company such as buildings, equipment etc.
- Proposed model is theoretical one and for the future purposes the question of real data arises: where real data can be obtained?
- The full implementation of simulation requires significant time and is out of scope of this work as it was concentrated on DNA representation.

The proposed model can be improved in the future by adding to business architecture of tangible and intangible assets genes that were not included in the baseline representation. Another application of PEST and other outer factors in the model is search of the best market for internally equal company.

Also, a simulation be means of Artificial life evolutionary algorithms: Genetic Algorithm will allow to model bunch of real-like companies, functioning on market. The Artificial Life modelling consist of three main steps:

- Finding the representation of individual (the goal of this paper)
- Defining of fitness function
- Implementation of GA evolution using genetics operators

The purpose of this paper is defining digital representation for A life simulation algorithm, that is the first step of Genetic Algorithms implementation. The synthesized model - Enterprise's DNA representation can be used in future works for further development of fitness function and biologic ally inspired modelling environment.

The reverse engineering methodology for fitness function design, that was proposed during the interviews looks like a very perspective approach that can help to overcome complexity and uncertainty of dependences between genes and fitness function value.

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