Smart Innovation Engineering System - A Tool for Facilitating Product Innovation Process

Mohammad Maqbool Waris, Cesar Sanin, Edward Szczerbicki

Abstract— For the survival and prosperity of the manufacturing unit, entrepreneurs need to find out new ideas that can be implemented in the products leading to innovation. The current study employs a systematic approach for product innovation. In this approach past experiences based on innovation decisions are stored and recalled during the innovation problem solving process. Implementing this system in the process of product innovation enables entrepreneurs and organizations to take enhanced innovative decisions at appropriate time. The system grows and matures with time gaining increasingly more expertise in its domain as it stores information, knowledge, and data related to the past formal decision events.

Index Terms— Decisional DNA, Product Design, Product Innovation, Set of Experience, Smart Innovation Engineering, Smart Knowledge Management System, Industrie 4.0.

1 Introduction

Since the beginning of life on Earth, humans are continuously gathering knowledge through experiences they face during their day to day activities. Fortunately, this knowledge is stored in human mind that can be easily recalled if similar situations arise. Moreover, based on previous experiences, humans are able to analyse smartly whenever a new task comes. Innovation can be described as making changes to the already established product by introducing something new. There are three types of possible approaches in solving innovative problem [1]: a flash of genius, empiric approach, and methodical approach. Out of these the methodical path is a systematic approach to solving the innovative problem. The current study employs the systematic approach to support the product innovation problem termed as Smart Innovation Engineering (SIE) System [2].

In this approach past experiences based on innovation decisions are stored in a Smart Knowledge Management System (SKMS) [3] and recalled during the innovation problem solving process. Such SKMS supports in providing quick optimal solutions to a particular innovative challenge. This system acts as a group or team of experts required to find a solution for innovative query. Moreover, the decision taken by this system can be quick due to current fast computational abilities. The proposed SKMS is based on the Set of Experience Knowledge Structure (SOEKS or SOE in short) and Decisional DNA (DDNA), which were first presented by [3], [4], [5] and later enhanced further for a number of dedicated domains[6], [7].

In section 2, the concepts leading to the research objectives are reviewed. These include the concept of Product Life Cycle and Product Innovation. Set of Experience knowledge Structure and Decisional DNA technique is also discussed that is implemented to perform the Smart Innovation Engineering process. In section 3, the research methodology is discussed in detail including the concept of Smart Innovation Engineering, Innovation process, its Decisional DNA and architecture. Working of the SIE system is also discussed at the end of this section. In section 4, concluding remarks are presented.

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2 Literature Review

2.1 Product Life Cycle

The life of a product is represented by Product Life Cycle (PLC). It generally consists of four phases, as shown in Figure 1, which are briefly described below:

Introduction: The product is designed and manufactured in the organization and then launched into the market. The cost of the new product is high due to less competition and sales rises slowly. The profits are negative due to high cost of research and development and marketing expenditure.

Growth: As sales increase due to improved product and market penetration, the profit increases resulting from lower production cost even if the cost of the product decreases due to more competition. At this stage more organizations jump into the business and start the manufacturing.

Maturity: The sales continues to increase and reaches the peak, the cost of the product is reduced to lowest due to sheer competition. The product is differentiated with other brands to attract the consumers.

Decline: The sales starts to decline that may be caused by introduction of better products, product substitution, trend and mood change.

Due to continuous rapid changes in the technology and preferences of the consumers, new products can no longer be developed by organizations solely based on their ideas [8]. The organizations need to consider the consumer needs and strategies adopted by their competitors. This will lead to a better innovative changes in the product at proper time.

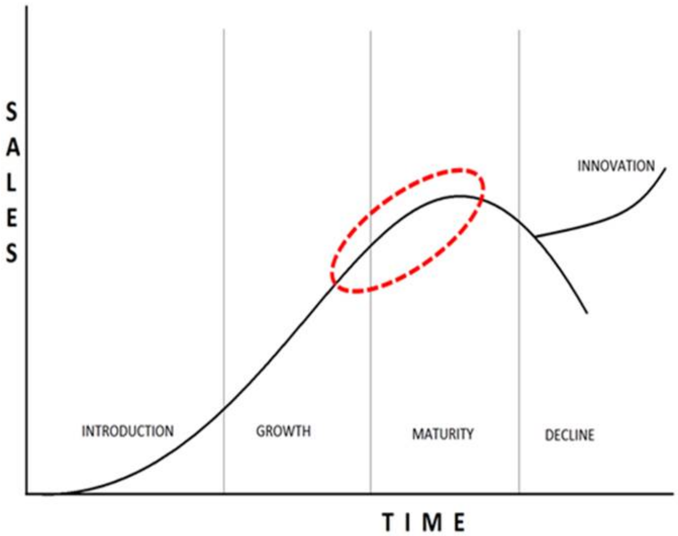

Fig. 1. The Product Life Cycle with the introduction of innovation critical zone

2.2 Product Innovation

Innovation is defined as the process of making changes to something established by introducing something new that adds value to users and contributes to the knowledge base of the organization [9]. Historically, Schumpeter [10] describes innovation as the use of an invention to create a new product or service resulting in the creation of some new demand. He termed it as creative destruction as the introduction of a new product into the market destroys the demand for existing products and creates demand for new ones. Innovation has been an important topic of study in various fields including economics, management science, business, engineering, science, hospitality, sociology, among others. Peter Drucker [11] defines innovation as the specific tool of entrepreneurs, the means by which they exploit changes as an opportunity for a different business or service.

2.3 Set of Experience Knowledge Structure and Decisional DNA

Set of Experience Knowledge Structure (SOE) is a smart knowledge structure capable of storing explicitly formal decision events [3], [12], [13]. This smart knowledge based decision support tool stores and maintains experiential knowledge and uses such experiences in decision-making when a query is presented in future. The SOE has four basic components: variables (V), functions (F), constraints (C) and rules (R) as seen in Figure 2 [4].

SOE variables are considered as the root of the structure as they are required to define other components. Functions are the relationships between a dependent variable and a set of input variables. Functions are used by the SOE for establishing links between variables and constructing multi-objective goals. Constraints are also functions that are used to set the limit to the feasible solutions and control system performance with respect to its goals. Rules, on the other hand, are the conditional relationships among the variables and are defined in terms of If-Then-Else statements.

A formal decision event is represented by a unique set of variables, functions, constraints and rules within the SOE. Groups of SOE are called chromosomes that represent a specific area within the organization and store decisional strategies for a category. Properly organized and grouped sets of chromosomes of the organization are collectively known as its Decisional DNA (DDNA).

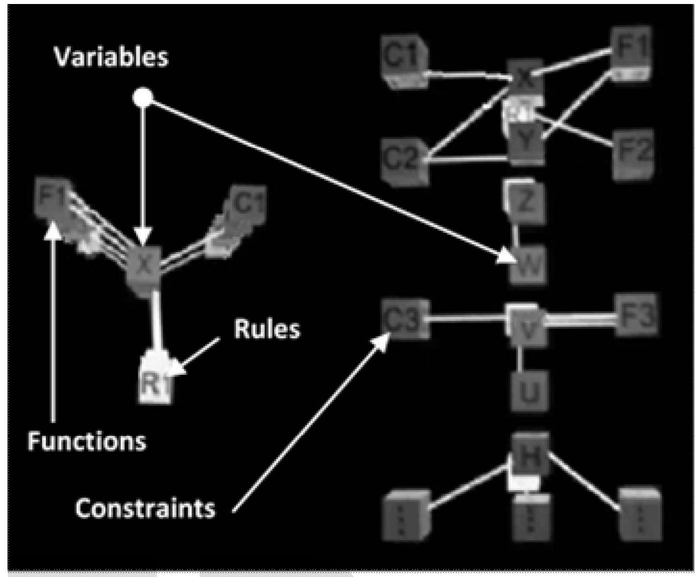

Fig. 2. SOE as a combination of four components (variables, functions, constraints, and rules)

3 Smart Innovation Engineering (SIE) System

Most of the time, organizations fail to predict the proper moment for analysing and applying innovation. They usually start the analysis process at the time when they should be already applying innovation. The most important questions encountered during innovation problem solving are: (i) when to innovate, and (ii) what to innovate? There is some point, a particular time, at which the organization needs to start analysing the innovative objective. Once this point is established and innovative objectives are defined, the innovation process can be started for finding optimal solutions, so that the required innovative changes can be implemented into the product on time. There must be clear difference between the point of analysing the innovative objective and the point of applying innovation. The time difference between these two accounts for the complete innovation process, i.e. analysis, innovative solution, design, manufacturing, and finally availability of the innovated product in the market. The recommended time for starting innovation analysis process is shown as a dotted circle in Figure 1 and is called the critical zone. This is the point in any Product Life Cycle at which the sales are still increasing but the rate of increase in sales starts decreasing.

After properly selecting the starting point of innovation analysis and implementing the required changes into the product, the innovated product can be launched into the market, at the end of the maturity phase or starting of the decline phase (Figure 1), increasing its sales. This cycle can be repeated. The above general product innovation procedure enhanced by application of SOE and DDNA will add smartness to the process and make it systematic, portable, and fast.

3.1 Innovation Process and its Decisional DNA

Based on innovative objectives, organizations can establish which features or functions of the product need to be upgraded, which ones may be excluded, and which new features or functions may be added to the product to improve its competitiveness [14]. In this approach we try to capture experiences related to any past innovation occurrence in dedicated SOEs. The unique SOE combination of variables (V), functions (F), constraints (C), and rules (R) represents experiential formal decisional event related to a given instant of innovation. A group of sets of experience of the same category is called a decisional innovation chromosome. Finally the innovation DDNA is the ultimate collection of decisional chromosomes and encapsulates knowledge for the whole domain in question.

Continuing with this case study illustrative example, a single innovation related decision associated with the Lifting System of the Screw Jack represents a set of experience, or decisional gene of the Lifting System. Subsequently, a number of such decisions, or sets of experience, associated with Lifting System will comprise its decisional chromosome. Similarly many such types of decisional chromosomes, like Input System chromosome and Housing chromosome will comprise a DDNA of the whole Screw Jack. These knowledge representation structures are never complete as they keep evolving and are upgraded with new decisions that are captured as SOE and added to the knowledge base. In this way the DDNA continues to gain new and updated experiential knowledge which helps it to support and enhance future decisions related to similar products having some common functions, sub-functions or components.

3.2 Architecture of a Product Innovation DDNA

The product innovation DDNA contains knowledge and experience related to each important feature of a product. This information is stored in eight basic modules of a product innovation DDNA (Figure 3): Characteristics, Functionality, Requirements, Connections, Process, Systems, Usability, and Cost.

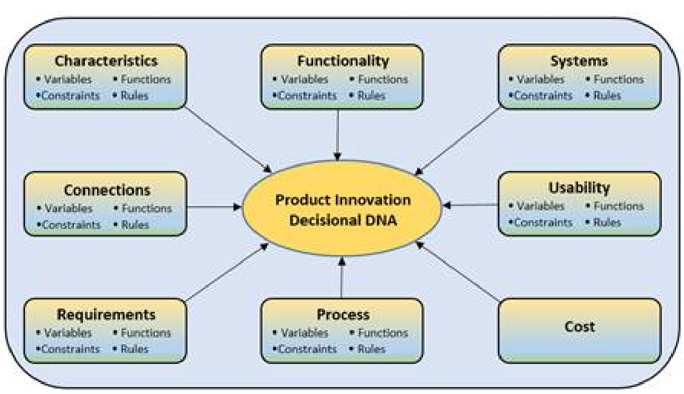

Fig. 3. Architecture of a Product Innovation DDNA

3.3 The Working of Smart Innovation Engineering System

The query based on innovative objectives is fed into the DDNA system. This query is converted to a SOE containing a unique combination of variables, functions, constraints and rules. The system then looks for the most similar SOE for comparison and based on the similar past innovation related experiences provides proposed possible solutions.

The system then compares the suggested possible alternatives for each component (that need to be replaced, deleted or added) in the Systems Module (Figure 3). These alternatives have specific weightage/rating for one or more attributes/properties they possess. This process is repeated for all the components selected for replacement. Similarly the solutions for the new components are selected based upon the priorities and weightage/rating of their attributes/properties. Once the lists of alternatives for all the components that need to be modified are selected by the system, it will present the list of proposed solutions containing the suitable alternatives for each components considering other constraints and rules among components (like hierarchy, logical connections and dependability relationships among components). Finally, the best solution is chosen from the list of proposed solutions and stored in the DDNA of the product innovation as a new SOE that can be used for solving innovative problem in the future. In this way the system gains some additional experiential knowledge with each query. Eventually, it behaves as an expert innovator/entrepreneur possessing knowledge equivalent to a group of experts capable of taking quick, smart innovative decisions.

4 Conclusion

This research introduces the concept of Smart Innovation Engineering that sup-port product innovation problems solving. The presented concept is based on knowledge representation structure that applies past experiential familiarities and carries the promise to support the innovation processes in a quick and efficient way. The SIE system will benefit the entrepreneurs and manufacturing organizations at it facilitates product innovation process, thus reducing the extent of dependa-bility on experts. Product innovation process can be performed quickly due to fast computational capabilities of the system. In this way, Smart Innovation Engineering system is one step forward in the direction of automation and Industrie 4.0.

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