*Decisional DNA, Set of Experience Knowledge Structure, Industrial Design, Virtual Engineering Objects*

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# USING DECISIONAL DNA TO ENHANCE INDUSTRIAL AND MANUFACTURING DESIGN: CONCEPTUAL APPROACH

During recent years, manufacturing organizations are facing market changes such as the need for short product life cycles, technological advancement, intense pressure from competitors and the continuous customers' expectation for high quality products at lower costs. In this scenario, knowledge and its associated engineering/management of every stage involved in the industrial design has become increasingly important for manufacturing companies in order to improve their performance and to take effective decisions. Knowledge based industrial design techniques have been used in the past with fair bit of success but they have their share of limitations like they may be time consuming, costly, domain specific and at times not very intelligent. This paper proposes a novel approach where the set of experience knowledge structure (SOEKS) and decisional DNA (DDNA) techniques are used for the experience based representation of engineering artefacts. The knowledge representation method that we propose; captures and re-uses the product and process involved within an engineering knowledge perspective. We also introduce in this paper a new concept that we call Virtual Engineering Object (VEO), which is a conceptual entity that permits a dual computerized/ real world representation of an engineering entity. It contains the embedment of the decisional model expressed within the set of experience, a geometric representation and the necessary means to relate such virtualization with the physical object being represented. VEO will act as a living representation of the object capable of adding, storing, improving and sharing knowledge through experience, in a way similar to an expert of that area.

## 1. BACKGROUND

The term industrial and manufacturing design used in this paper can be defined as an integration of the knowledge of product and process of an object, to demonstrate its design and manufacturing functions. Industrial design (ID) is a complex process in-

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volving knowledge of various fields. Increasingly competitive and demanding markets are forcing companies to search for means to decrease time and costs for new product development, while satisfying customer requirements and maintaining design quality [1].

A successful industrial design is one which;

- meet a high number of product requirements,
- enable robust manufacturing with high quality,
- deliver sound profits on competitive markets,
- fulfil customer expectations,
- enable a sustainable future [2].

A well-recognized feature of design is that a large percentage of the product's life cycle time is spent on the routine tasks as it takes up-to 80% of the design time. It is noted, 'around 20% of the designer's time is spent searching for and absorbing information', and '40% of all design information requirements are currently met by personal stores, even though more suitable information may be available from other sources' [3]. *This implies that design information and knowledge is not represented in a shared and easily accessible knowledge base.*

There are a number of strong arguments for adopting computer integrated knowledge based manufacturing system to meet the above discussed features for successful ID. One of the hallmarks of the knowledge base systems is to automate repetitive, non-creative design tasks. Not only does automation permit significant time and cost savings, it also frees up time for creativity, which allows exploration of a larger part of the design envelope. Clearly, in such cases *knowledge re-use guided framework may save considerable time and effort* [1].

Due to the complex nature of modern industrial design there are few challenges of using knowledge based manufacturing system like;

- The knowledge for the desired application is not available.
- The technology in the design process is constantly changing.
- Knowledge outputs are not compatible with other systems.
- Knowledge outputs not easily understandable and readable.
- Knowledge capture is not performed in real-time, adding new knowledge to the repository is performed manually [4].

In this paper we introduce a smart knowledge based decision support tool, Set of Experience Knowledge Structure (SOEKS) and Decisional DNA (DDNA) [5]. The SOEKS has been developed to store formal decision events explicitly. It is a model based upon existing and available knowledge. *It can be described as a knowledge structure to retain explicit experiential knowledge* [6].The proposed concept of VEO will be powered by SOEKS and DDNA. That means a VEO will not only be a knowledge repository but it will have qualities like self-awareness and reflexivity embedded inside it. And all these features will enable a VEO to behave as a live object.

The structure of this paper is as follows. The section 1, describes the concepts and structure SOEKS and DDNA. In section 3, we introduce the idea of semantic in ID. In section 4 the architecture of VEO is discussed. After discussing the concepts and implementation in section 5, we discuss conclusions of this paper in section 6.

## 2. SET OF EXPERIENCE KNOWLEDGE STRUCTURE (SOEKS) AND DECISIONAL DNA (DDNA)

As discussed in section 1, a large amount of previous knowledge is needed to design a new component; the information may not be exactly the same but may be from the family of the related object. But it has been observed that not much effort is made to retain the knowledge. Knowledge and experience are lost indicating that there is a clear deficiency on experience collection and reuse. Some of the reasons are:

a) the non-existence of a common knowledge-experience structure able to collect multi-domain formal decision events, and
b) the non-existence of a technology able to capture, store, improve, retrieve and reuse such collected experience [7].

Sanin and Szczerbicki proposed a new smart knowledge based decision support tool, having three important elements:

a) a knowledge structure able to store and maintain experiential knowledge, that is, the SOEKS and the Decisional DNA,
b) a solution for collecting experience that can be applied to multiple applications from different domains, that is, a multi-domain knowledge structure, and
c) a way to automate decision making by using such experience, that is, retrieve collected experience by answering a query presented [5, 6].

The SOEKS is a compound of variables (V), functions (F), constraints (C) and rules (R), which is uniquely combined to represent a formal decision event. Functions define relations between a dependent variable and a set of input variables; therefore, SOEKS uses functions as a way to establish links among variables and to construct multi-objective goals (i.e., multiple functions). Similarly, constraints are functions that act as a way to limit possibilities, restrict the set of possible solutions, and control the performance of the system with respect to its goals. Finally, rules are used to represent inferences and correlate actions with the conditions under which they should be executed. Rules are relationships that operate in the universe of variables and express the connection between a condition and a consequence in the form if then else [8].

Chromosomes are groups of set of experience (SOE) that can accumulate decisional strategies for a specific area of an organization. Multiple SOE can be collected, classified, and organized according to their efficiency, grouping them into decisional chromosomes. Finally, sets of chromosomes comprise what is called the Decisional DNA of the organization as shown in Figure 1.

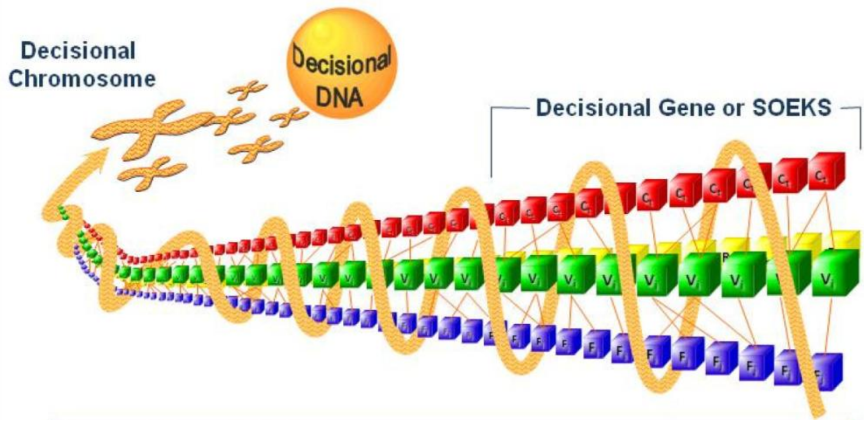


Fig. 1. SOEKS and Decisional DNA [7, 9]

## 3. SEMANTICS IN ID

*Semantics is the discipline that studies the meaning of things*. Semantic technologies compose some of the most motivating technologies resulted from the World Wide Web revolution that is frequently reviewed in different areas of knowledge engineering. Semantic web is the new-generation web that tries to represent information such that it can be used by machines not just for display purposes, but for automation, integration, and reuse [10].

Semantics in ID is based on the description of the states that can be identified in a manufacturing process (situations), the task to be performed in each situation (actions) and the rules to determine the next situation after a task is executed (decisions). The semantic representation of information enables the creation of intelligent systems, which can interpret and understand potentially automated tasks, harnessing added-value decision-making processes. Particularly, the semantic web can provide a cutting-edge formal representation and knowledge-driven set of technologies to enable automation of industrial manufacturing processes [11].

## 4. VIRTUAL ENGINEERING OBJECT (VEO)

According to our definition, a *Virtual Engineering Object (VEO) is a knowledge representation of an engineering artefact comprising experience models, domain and functionality along a physical attachment to the virtual object in its conceptualization.* VEO model intends to be the most complete possible model for a specified domain and can be used in multi domains.

As discussed in section 1, large portion of the design time is spent on the routine tasks, which have already been designed previously. Not much work has been done to store and reuse this information. Lot time and money is wasted in searching this information. This approach will automate repetitive and non-creative design tasks.

The objective of this study is to develop the concept of VEO using SOEKS and DDNA. A VEO should have all the possible feature of an artefact along with its past experience embedded in it.

VEO will enhance the industrial and manufacturing design, as it will be the union of knowledge and experience. It will embody information of all the aspects involved in the manufacturing of that particular object like process, resource and calculations related to it. DDNA will have the experiential knowledge of its characteristics, requirements, functionality, connections and present state of that object. VEO model is discussed in detail in the section 5.

## 5. CONCEPTUAL ARCHITECTURE AND FORMULATION OF VEO

As discussed in previous section that a VEO will have a knowledge base of an object then we will infuse the experience of DDNA in to it. Figure 2 show the architecture of a proposed VEO. This framework includes preliminary design and preliminary process knowledge. This model will be having manufacturing information on preliminary process planning, such as processes, sequences, parameters, cost/time etc. The experience of DDNA will provide the associated knowledge to the above parameters, which in turn make the decision making easier and intelligent [5].

Process knowledge is classified into three main types based on their forms, as shown in Fig. 2 [12]. They are:

(1) *Knowledge of process:* This kind of rule-based knowledge includes the feature process, the product process, and the typical process.

(2) A feature is the definition of a component’s basic geometric entities for manufacturing which can include cylinder, hole, plane, etc.

(3) Product process knowledge refers to process route information of a product family or similar products, which may change according to the input manufacturing data.

(4) The typical process knowledge is the mature process route information which has been validated by practice and normally used more frequently.

(5) *Knowledge of resource*: This refers to static manufacturing resource information, which includes all kinds of process resources, such as machine tools, fixtures, cutters, machining data, and materials.

(6) *Knowledge of calculation*: This refers to knowledge obtained through calculation. In process planning, the selection of working hours and material quota is a regular process.

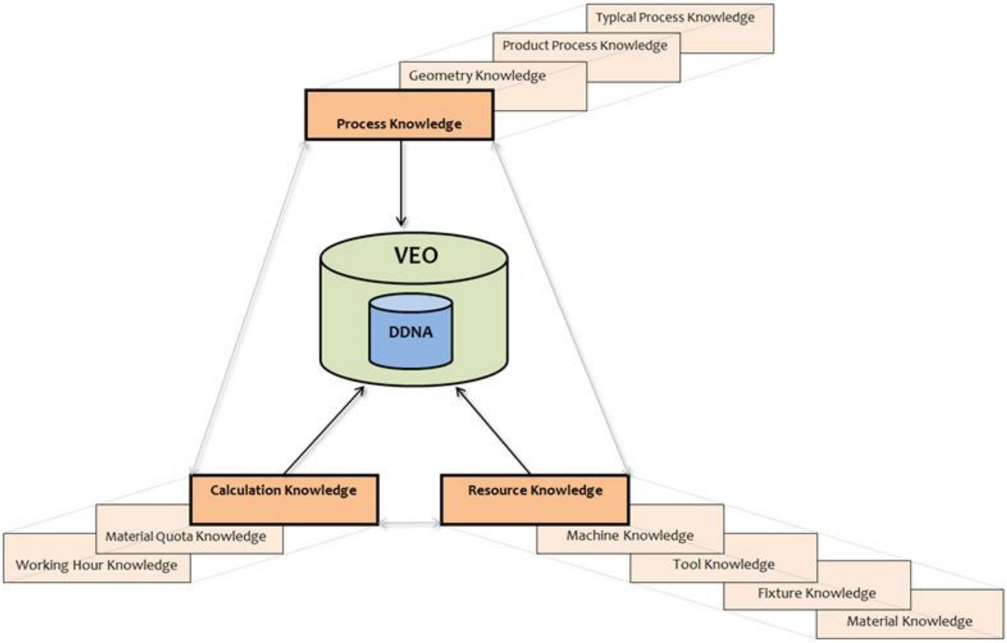


Fig. 2. Architecture of the proposed VEO

DDNA will have the following experience in it:

(1) *Characteristics* describe not only the set of expected benefits offered by the process, resource, calculation selected for a particular object, but also artefact represented by the Virtual Engineering Object. Such characteristics will depend on what kind of artefact are we considering. For example characteristics of a process can be the relative motion between a tool and a work-piece. While that of a resource, like tool is what specific actions it takes.

(2) *Requirements* describe the set of necessities of the knowledge base and the Virtual Engineering Object for its correct working. The set of requirements depends on what kind of VEO are we considering; for a Lathe machine work holding device, tool holder, power source etc. as the essential requirements.

(3) *Connections* describe how the Virtual Engineering Object is related with other VEOs. These connections can be of different types. Some of them can be a need relationship, e.g. a gear is part of an engine or the machining parameters like feed, depth of cut and cutting speed of different machines.

(4) *The present state* of the Virtual Engineering Object indicates parameters of the VEO at the current moment. For example, questions like *how* much time has been this machine powered on? Or what is the current performance of this machine, cell, shop etc.?

As an example Figure 3 show knowledge structure of a manufacturing unit. If we want to extract VEO for a drilling, the shaded modules will be required as shown in the figure.The design information, which includes the requirements, behavior, function, form and structure of an artifact, will be provided for product design based on the manufacturing process model, and to enhance design specification.

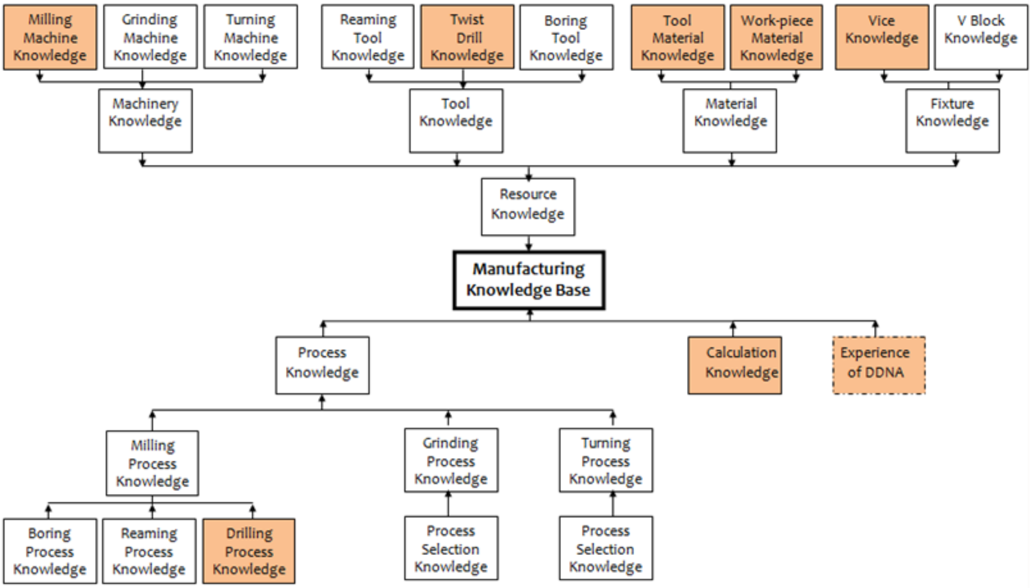


Fig. 3. Knowledge structure of a manufacturing unit

The dynamic and static knowledge and experience will be stored in the chromosome VEO of a drilling machine. Each time a manufacturing, maintenance or repair operation is done on the drilling machine the experience and knowledge is added in the VEO.

The VEO of a drilling machine will be a combination of various other chromosomes and VEO like the VEO of a tool used and the VEO of a work piece holding device. These different VEO's will be joined according to common link or functionality.

This VEO will behave as an expert of the drilling machine. When an operator will try to use this drilling machine of a particular machining operation, he can consult the VEO and it will provide all the possible knowledge, based on the previous experience on this machine.

On final integration of all the knowledge base of the design process and all the VEO, the virtual engineering object of the desired product is obtained. This VEO of the product will have experience and knowledge involved at each and each every stage of the product design process right from its inception to the final product. This VEO will keep evolving with each formal decision taken related to the particular product.

## 6. IMPLEMENTATION

Using, channelizing and exploiting previous knowledge in industrial design is an area which is not been researched extensively as yet. Sanin and Szczerbiwki have applied the concept Set of experience knowledge structure (SOEKS) and Decisional DNA in various other domains [13]. The challenge for this research is to apply this concept the manufacturing and design area on framework discussed in section 5.

The proposed approach to the solution of this issue is to systematically create, capture, reuse, and distribute experience in the work processes of an organization, preventing important decisional steps from being forgotten in the daily operation or research tasks, and supporting a path towards appropriate automation for recurring tasks or findings.

The main objective of this work is to apply the concept of SOEKS/DDNA on the industrial design process. On the conceptual level, set of experience will be applied on every phase of the design process i.e. mechanism to capture knowledge experience and formal decision taken in day to day operations will be developed and then it will be reused. All the important features of every design stage and its integration with SOEKS will be elaborated.

The practical implementation of SOEKS/DDNA is done on the manufacturing and production phase. Principle adopted for implementing SOEKS at every stage is the dividing a system into subsystems or modules [14]. The knowledge base of the production phase of the product design is broadly divided into Resource knowledge, Process knowledge and calculation knowledge, which are further divided into subsystems as shown in figure 2. When we integrate the experience of DDNA with this knowledge base, the concept of virtual engineering object (VEO) is developed.

In this project, we focus on the adaptation and creation of new algorithms to perform good virtual experience analysis, based on the idea of introducing semantics into the data modeling and processing in industrial design and manufacturing system. ID user knowledge gathering is still not addressed from a semantic point of view. SOEKS would able to model it. We need to accomplish four key tasks to enhance ID by utilizing SOEKS and Decisional DNA:

*Task 1: Data Pre-processing and Semantic Representation*. Knowledge is a combination of experiences expressed in terms of values, related information, and expert insight, which provides the framework for evaluating and incorporating new experiences and knowledge. Thus, there are four basic components that surround decision-making events: variables, functions, constraints, and rules. We need to propose new ways to pre-process and represent industrial design or manufacturing processes in the forms of Decisional DNA.

*Task 2: Data Collection and Generalization*. Establish techniques for collecting industrial design or manufacturing processes knowledge and transform it into Decisional DNA according to the models developed in Task 1. Afterwards, mixing of the collected knowledge and establishing a combination model for formal decision events is required.

*Task 3: Evolving Knowledge Base on Industrial Design.* Combined models from Task 2 open possibilities for knowledge evolving techniques based on industrial design which leads to sub-solutions. The developed approach will reduce the gap between different proposed knowledge trying to solve similar problems and will look for a holistic encounter point of their solutions.

*Task 4: Establishing Techniques for Manipulating, Administrating and Sharing of Collected Engineering Design Decisional DNA*. Decisional DNA as a knowledge representation for formal decision events is recognized as the fundamental component of infrastructure for advanced approaches to intelligent knowledge management and knowledge engineering automation. The experience-based knowledge structure represented by Ontologies will facilitate the achievement of this aim while allowing for an easy sharing of Decisional DNA[15].

## 7. CONCLUSION

Existing conceptual approach have proposed to enhance ID and manufacturing system in industrial plants by supporting decision making system and systemize organization of knowledge. This knowledge management approach introduced knowledge based structure and architecture to enhance ID by utilizing SOEKS and Decisional DNA in manufacturing system. The concept of VEO will behave a knowledge and experience repository. These VEO's of explicit knowledge can be shared among similar organizations, industries, and partners to build up a decisional repository. This decisional repository will save significant time and money as the right information, in the right format and at the right will be available.

The main contribution of our idea is the procedure to classify types of manufacturing design knowledge and knowledge structure to support manufacturing knowledge maintenance, also an appropriate methodology to utilize manufacturing knowledge models to industrial design by utilizing SOEKS and Decisional DNA.

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