CIRP Journal of Manufacturing Science and Technology 1 (2009) 131–136

Contents lists available at ScienceDirect

CIRP Journal of Manufacturing Science and Technology

journal homepage: www.elsevier.com/locate/cirpj

Assisting R&D activities definition through problem mapping

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ARTICLE INFO

Article history:
Available online 6 December 2008

Keywords:
Inventive design
TRIZ
Problem network
Contradiction network
R&D activities

ABSTRACT

Problem formulation and problem solving has always been identified as a key activity in design, moreover in the context of innovation. Nevertheless, few research findings have led to a practical use in enterprises since a large part of today's industrial world is still under cost reduction and quality maintenance concerns. This paper has the aim of presenting the theoretical grounding of a new problem-oriented approach and the way we translated it into generic techniques through a simple and didactic example. A discussion section summarizes actual statement, advantages and limitation of our approach so as further research orientations.

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1. Introduction

1.1. Inventing or optimizing?

The paradigm in which our contribution resides concerns invention. Our reflections take place with the organization of innovation and propose a reflection towards the fact that an efficient inventive activity will positively influence the overall result of innovation within an organization. To introduce our contribution we would like to start by stating on the major differences which separate innovation's paradigm from optimization one.

The orientation which engineering design undertakes since a few decades is turned towards optimization [1]. It tends to obtain the best possible result on the basis of a whole set of known elements. The example can be taken to optimize thickness of a part's walls respectfully to laws of mechanics, the best possible choice of a material constitutive of a mechanism. In the case, for example, of a design of a mechanism answering a precise set of requirements, optimization design (OD, also called routine design) will then employ a procedure based on the most efficient way, taking into consideration all elements at disposal of designers (from their respective knowledge) or resulting from their research findings (state of the art, surveys). This type of process is largely inspired by the reflex of compromise when choices in opposition are posed to designers (the body of a mechanism having to be both thick to be resistant mechanically and thin to be light). The criteria involved here are primarily mechanical laws, the use of a potential specific material in the design of the body and the restrictive specific conditions imposed by the situation of the object's life (space roominess, safety, norms to be respected).

A contrario, inventive design (ID) identifies situations of opposed features as being sources of key problems to be solved by the refusal of a compromise [2]. The compromise is here characterized as the acceptance to reduce ambitions of one of the dimensions of design orientation (to design a rigid body) for the limited benefit of the other (to design a body "not too heavy"). The objective of ID is thus to refuse compromise while formulating an inventive challenge and to assume the fact that the goal of the act of design leads to "both" a resistant and light body. Let us add that elements of knowledge being able to become actor of the resolution are probably unknown to the designer or not highlighted by the sequencing of events in the design process. It is essential thus that an ID process assumes its two major difficulties: to assist the formulation of the whole set of problems raised by the act of design of an evolving object and to assist the revealing of non-existent elements of knowledge at the origin of the design process, allowing to refuse compromise and to solve the problem. In our example, physics of the soap bubble and in particular the study of the phenomena of tensile surface stress has opened a field of research (the concept of foam) as potentially a way to solve inventively the opposition between mechanical resistance and mass [3].

To finish on this subject, there are different postulates between OD and ID, the first remains the most legitimate reflex under the paradigm of quality (to improve the concept of value, to reduce costs, to ever assume new functionalities) whereas the second is proven to be useful under the paradigm of invention (to create the

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1755-5817/$ – see front matter © 2008 CIRP.
doi:10.1016/j.cirpj.2008.09.014

new, what does not exist yet). We can even go further in postulating that ID seems an unavoidable way as soon as OD shows an exhausted space of potential improvement when the best possible compromise is found and maintained [4].

In short, OD presupposes a problem well posed and documented, adapted to certain contexts, while ID is more adapted to situations where the problem is badly formulated, where a certain amount of interpretation are to be made and in a context where the willingness to innovate is strong. Cross in [5] is presenting a typology of design problems where the distinction between two types of problems is fundamental: those which presuppose the existence of a structure of the problem "objectified" existing a priori and the others who partially sees design rather as a co-evolution where the process consists in developing and simultaneously refining formulation and the ideas for synthesizing a solution.

1.2. From design problems to designer's problem solving behavior

As one of the most universal and prevalent thinking activities [6] problem solving (PS) is in use every day in company R&D departments. PS concerns small and medium enterprises as much as large corporations and is claimed to be "the most important aspect of any job" [7]. Since thinking activities related to PS become crucial in R&D departments, the need arises to manage their efficiency, taking into consideration the difficulty of adapting to the changed circumstances present in this innovation age. As an example, habits inherited from quality era have forced decision makers to optimize the budget of advanced R&D while at the same time the global context forces enterprises to launch inventive activities, often resulting in ill conceived, high risk investments [8].

Among the leading methodologies currently used in industry for improving the relevance of decision making, Six-Sigma has gained legitimacy. This leadership is mostly due to the ease with which it can justify ROI when implemented. Nevertheless, although this objective seems very respectable; Six-Sigma contains only basic statistical rules aimed at optimization. We can even state that no significant inventive results can arise from optimization, thus, Six-Sigma is a tool for quality concerns, not for inventing. Therefore, the management of inventive problem solving activities (IPSA) is still to be addressed.

The role of IPSA in R&D departments has been the subject of very few research studies, since these activities are often presented as similar to traditional R&D activities (RDA) [9], stated as being tacitly inventive. We disagree with this, claiming instead that there are different types of RDA whose particularities are to be "inventive" or "traditional". Inventive RDA requires the use of knowledge or know-how from a substantially different technical domain. In this context, knowledge management (KM) has also become an activity to be optimized, since the use of available knowledge for understanding the initial situation and the problem definition will significantly affect the resulting efficiency of the inventive R&D process.

1.3. The role of knowledge in R&D

The crucial role held by knowledge in R&D's efficiency has often been described [10]. A review of published work on this subject reveals substantial contributions from both management and human sciences. In the sciences of engineering, researchers in information systems have long underlined the difficulties of organizing the flow of Kn [11]. Despite these numerous contributions and intensive research findings, Kn management (KM) is qualified by [12] as having "...a mediocre success record in companies." The arguments brought forward by the authors for justifying their assertion are that the problems of transmission from person to person and the difficulties of harmonization of aims between management and engineers mean that efficient organizational learning has yet to be achieved.

In a previous paper, we have already expressed the need to link knowledge representation and problem solving logic [13]. Our hypothesis was that the use of the contradiction axiom (as developed in the theory of inventive problem solving) will partially address the issues of complexity reduction, problem representation and problem management, thereby orienting and assisting problem resolution stages.

Our aim in this paper is to propose a framework for processing and representing relevant elements of Kn resulting in an efficient assistance for planning R&D activities.

2. Towards a methodological development

2.1. A model for problem representation

The suggested model contributing to innovation activities management rely on the assumption that inventive activities must evolve towards the resolution of revealed "inventive challenges".

This is why we start from a set of notions posed a priori which have the role to drive knowledge acquisition process so as to facilitate innovation: the main concept advocates that a design problem must be associated to a contradiction oriented formalism which will be further detailed. In sort, a problem is a contradiction (as it is stated in [14]). A contradiction describes the problem precisely at its axiomatic level. A contradiction is representative of a clearly expressed inventive challenge to be solved for the concerned system. Then, the undertaken direction to assume inventiveness is to solve it without compromise. In priority, the whole set of contradictions useful for problems definition of the studied domain needs to be disclosed and the links between these contradictions established. The concept of contradiction is axiomatically described by E–N–V formalism (element-name of the feature-value) brought from OTSM-TRIZ [15] so as influences parameters have between them: the modification of a value of a parameter in a given direction induces the modification of another. These components are to be extracted, completed and validate by the concerned domain experts so as by other actors of the project.

In the model suggested through this article, we start from the principle that the methodology employed must propose a problem representation formalism, formally defined in order to offer to designers a simple and shareable model (easy to manipulate by a computer). The attributes towards which we intend to move for this formulation phase are:

- *Speed*: the speed to which knowledge of the experts fields passes from tacit, to explicit then formalized stage.
- *Universality*: the capacity of the formalism to be accepted at various departments, services, persons of the company.
- *Representativeness*: the capacity of the model to give project actors a clear and reliable representation of the whole set of problems within the scope of the study.
- *Dynamicity*: the easiness of the model to be permanently updated.

2.2. Two fundamentals brought to TRIZ

For a few years TRIZ is observed and appreciated as a set of theoretical and methodological elements assisting the creative phases of the product/systems design process. Regarding this statement we would like to underline that current uses of elements of this theory of inventive problem solving associated with

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