Izabela KUTSCHENREITER-PRASZKIEWICZ*

CHOSEN PROBLEMS OF MODELLING ENGINEERING DESIGN PROCESS

Abstract

An overview of the various models for engineering design process was presented. General Design Theory, Basic Model, Real Design Model were described. Type-2 fuzzy sets implementation on engineering design process was described.

1. INTRODUCTION

Product development and design are directly connected with the enterprise strategy and the marketing research results. The designer is to create new products or to modify the old ones according to the marketing department's demand. The product must fulfil the requested technical parameters, but also the demands concerning the economical production, quality and reliability [14].

A company, to be competitive must continuously improve its products and processes. The development of company can be realized using its own human potential, or using transfer of technique. The transfer of technique can be realized using formal or informal methods (Fig. 1). The formal methods are for example: purchase of licence, patents, use of consulting firm. The informal methods are: exchange of technical staff, conferences, trade, exhibition, professional training.

An example of the direction of research and development work was presented on Fig. 2. Design process is a halfway between research process and routine organization procedure of production preparation.

Development and research work is connected with uncertainty and risk. Risk is connected with internal and external factors. Internal factors include: human mistakes, information computing mistakes, machine failure. The external factors include change of law, atmospheric conditions.(Fig. 3).

The goal of the article is to create mathematical framework for modeling by words engineering design process.

* Ph.D. Izabela Kutschenreiter-Praszkiewicz jest adiunktem w Katedrze Inżynierii Produkcji w Akademii Techniczno-Humanistycznej w Bielsku-Białej, e-mail: Ipraszkiewicz@ath.bielsko.pl

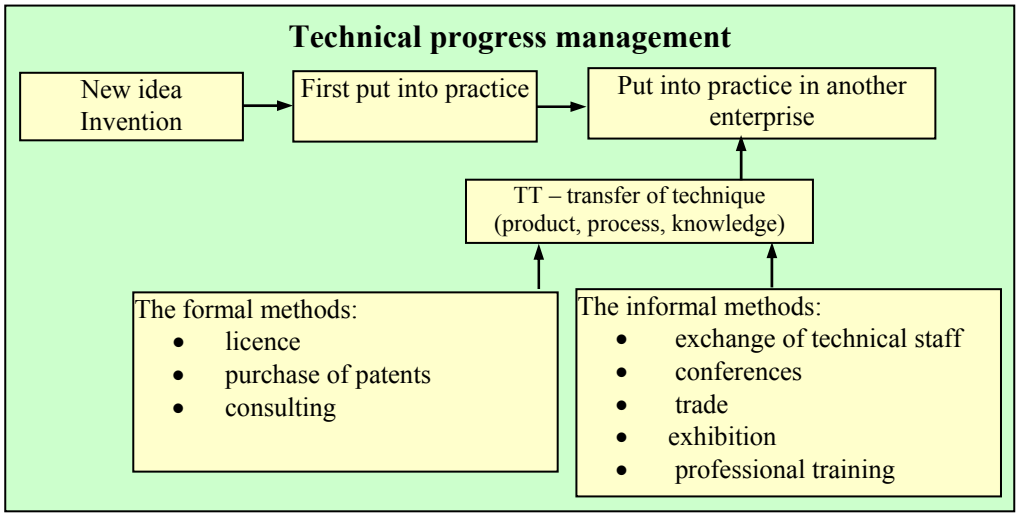

Fig. 1. Technical progress management

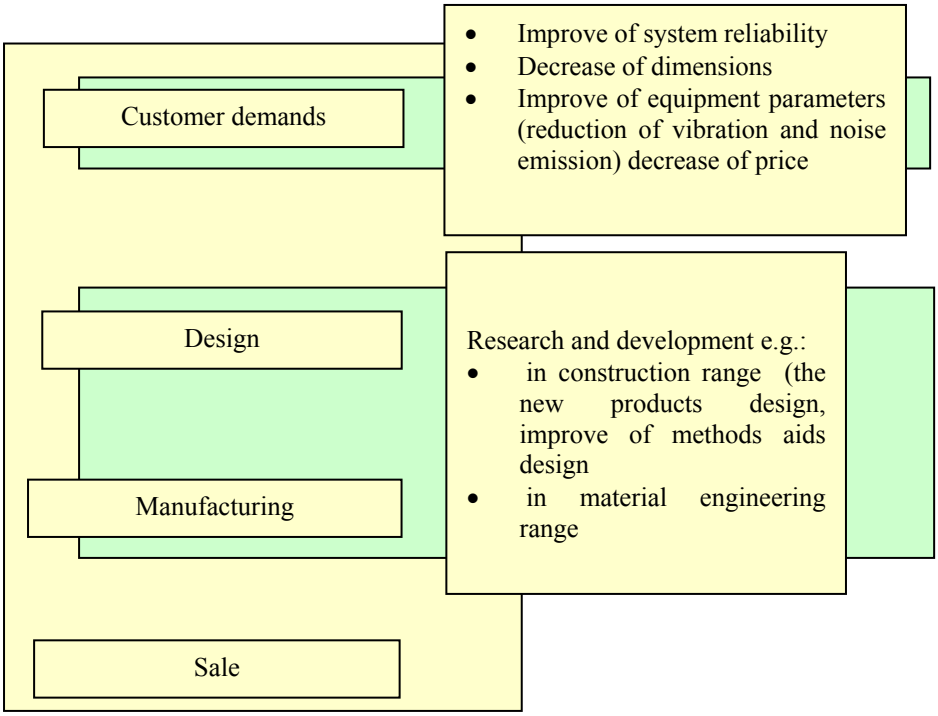

Fig. 2. Research and development trends

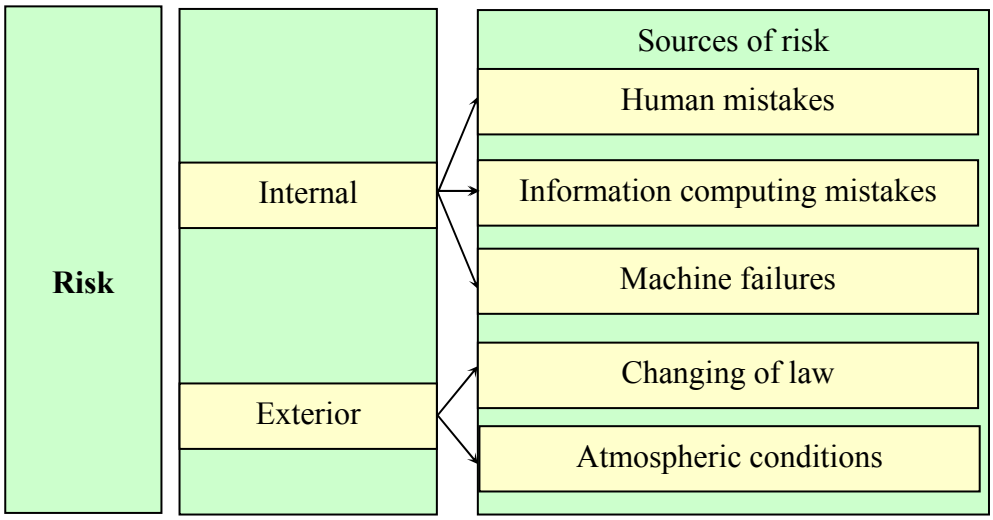

Fig. 3. Source of risk

2. REVIEW OF CHOSEN MODELS FOR ENGINEERING DESIGN PROCESS

Mathematical formalisms of design have been of great interest to many researchers over the years [16], [5], [6], [4], [9], [13]. General Design Theory formulated by Yoshikawa [20] is a well known one. General theory of design is based on topological model of human intelligence. Topological models use for modelling objects description definition, axiom and theorem. This approach is based on the idea that design is set of entities and consequent definitions. From that definition it is possible to state axioms [16]. The following three axioms are presented in GDT as the basic properties of these concepts: axiom of recognition (any entity can be recognized or described by the attributes), axiom of correspondence (the entity set S' and the set of concept of entity S [15] have one to one correspondence), axiom of operation (the set of abstract concept[16] is a topology of the set of entity concept[17]).

In GDT, there are two kinds of knowledge for design: the ideal knowledge and the real knowledge. The three axioms are valid only on the ideal knowledge. The ideal knowledge is represented by two topological spaces: the functional and the attribute space and a map between these topologies. Design is basically an activity, which connects design specification (denoted by functional concept set) and design solution (denoted by attribute set) [13].

[15] The entity set S is e set which includes all entities in it as elements. By all entities, we mean entities which existed in the past, are existing presently and will exist in future. This set is denoted by S'[9].
[16] The set of abstract concepts is derived by the classification of concepts of entity according to the meaning or the value of entity [9].
[17] Concept of entity is concept which one has formed according to the actual experience of an entity [9]

Design solution is obtained immediately after the specification is described without design process in the ideal knowledge. Design is not necessary under the ideal knowledge. This situation is called by Kikichi i Nagasaka [9] a paradox of GDT.

Braha and Reich [4] based on [1], [2], [3], [7], [19] developed basic model for design process. The basic model formulates design as a process that starts from abstract specification such as customer needs or functional requirements in the function space. The designer matches partial structural information in the structural space, with the current refined specification [4]. The process continues until the solution is obtained.(f_i is the current tentative specification list and f_{i+1} is a proximal refined specification list). A design process is obtained by selecting at each refinement stage a single generating element out of many possible ones. The basic model has many limitations and some aspects of real design do not captured by the model, i.e. multifold mappings between the functional and structure space, feedback loops. Because of those limitation Braha and Reich [4] developed more realistic model called real design model. This model captures the interplay between design descriptions, each of which is represented by a pair of functional and structural descriptions <f,d> [4]. The designer starts with the initial design description <fo, do> (fo - means initial specification, do - means initial context descriptions). During creation of a new design description both functional fi and structural di description can be refined (Fig. 4).

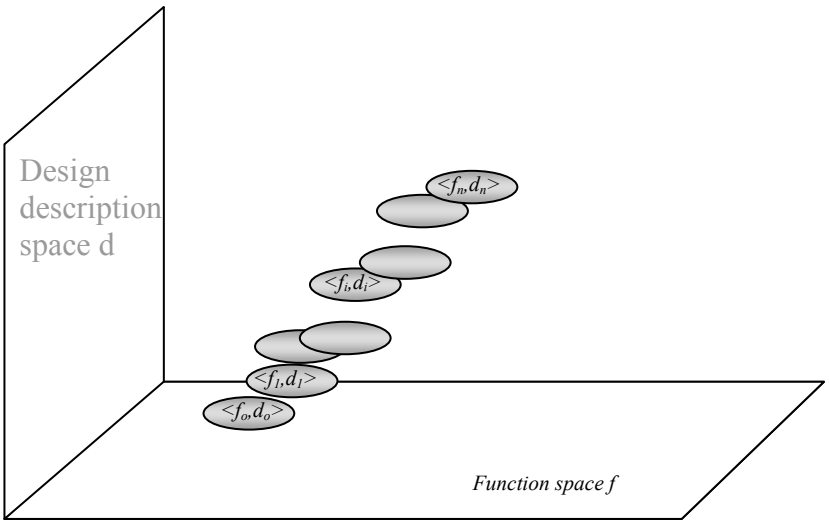

Fig. 4. Design process (developed based on [4])

3. APPLICATION OF ARTIFICIAL NEURAL NETWORK FOR DETERMINATION TIME CONSUMPTION IN DESIGN

Design process required more detailed analysis of process then it was described in previous part of the article.

Methods described above are connected with topological structures for engineering process design. The design process is connected with time and labour consumption (Fig. 5). Next part of article describes how to determine time consumption of design process.

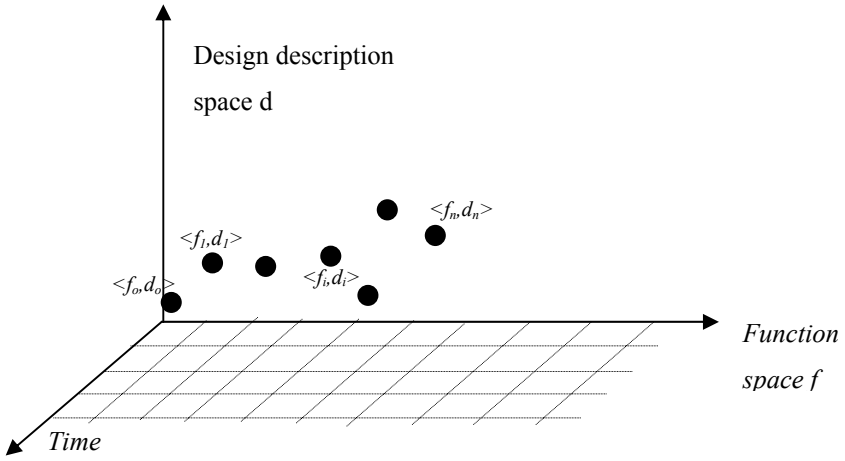

Fig. 5. Design process

We can received the time consumption data using neural network.

Artificial neural network are electrical analogue of the biological neurons system. A typical artificial neuron is mathematically represented by two modules: a linear activation and non-linearity that limits the signal levels within a finite band. Neurons in an artificial neural net are connected in different topological configuration. Two most common type of configurations are feed-forward and feedback topology. Usually, a feed-forward network contains a number of layers, each layer consisting of a number of neurons. Signal propagation in such networks usually take place in the forward direction only, signals from the I-th layer can be propagated to any layer following the – th layer, for i ≥ 1. In the recurrent neural network, there exists feedback from one or more neurons to other.

Informally "encoding" or "learning" refers to adaptation of weights in a neural net. Thus until the weights converge to a steady state value, the process of encoding is continued. Adaptation of weights can be accomplished in a neural net by for different ways:

- supervised learning – employs a trainer, who provides the input-output training instances of given neural net.
- unsupervised learning – unlike supervised learning, an unsupervised learning requires no teacher. Consequently, there is no target outputs. During the training phase, the neural net categorizes the received input patterns into different classes.
- competitive learning – competitive learning process are usually represented as artificial neural systems with self-existing recurrent connections.
- reinforcement learning – weights are reinforced for properly performed actions and penalized for poorly performed actions.

There are about 30 different NN architectures, which are being employed in research at present (Suthomaya, Tannock, 2005). Each NN architecture and training algorithm combination is suitable for different situation, depending on what kind of work the network is expected to do. The network adopted in the case study below was the multi-layered perceptron (Fig.6).

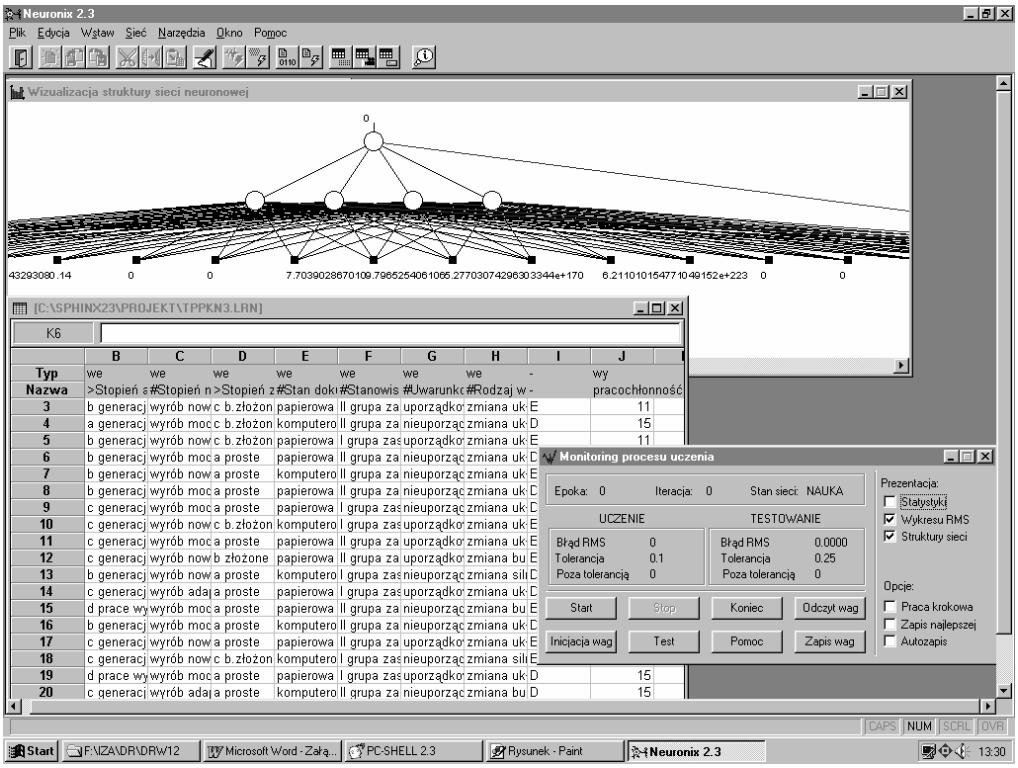

Fig. 6. Neural network

The SPHINX packet including NEURONIX module, which is the simulator of the neural network, was used in the example.

4. IMPLEMENTATION FUZZY SETS IN ENGINEERING DESIGN PROCESS

Fuzzy sets have been around for nearly 40 years and have found many applications [11].

Membership functions of type-1 fuzzy sets are two-dimensional, whereas membership functions of type-2 fuzzy sets are three-dimensional. A type-2 fuzzy set provides additional degrees of freedom that make it possible to directly model uncertainties.

A type-2 fuzzy set [10] is characterized by a type-2 membership function $\mu_A(x,u)$ where $x \in X$ and $u \in J_x \subseteq [0,1]$.

$$A = \{((x,u), \mu_A(x,u)) \mid \forall x \in X, \forall u \in J_x \subseteq [0,1]\} \qquad (1)$$

where $0 < \mu_A(x,u) < 1$.

In real design it is necessary to distinguish intermediate stages which are required to make the decision whether to continue the design process or not.

Engineering design process requires dividing analysis into stages. After each stage the probability of continuing the design process is going to be analysed. It will be analysed linguistically - in words. For modelling this process fuzzy set type II can be used. (Fig. 7).

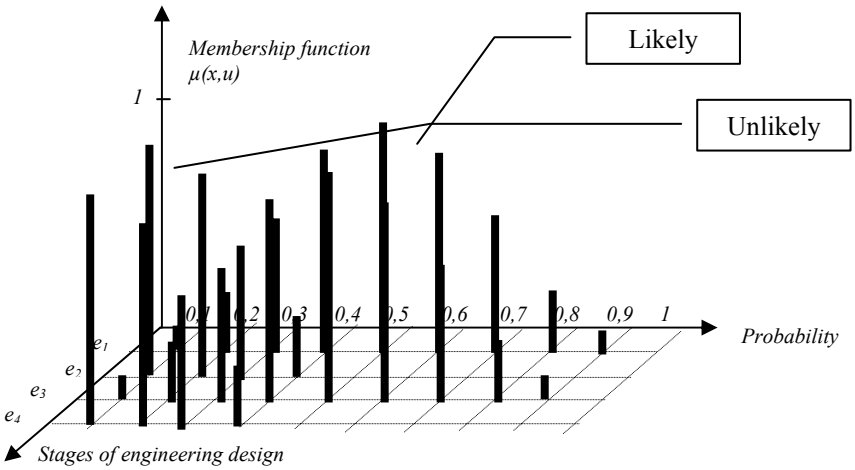

Fig. 7. Example of a type-2 membership function

4. CONCLUSION

Development and research work is connected with uncertainty and risk. Many models for engineering design process are described in literature but it is necessary develop a new one which uncertainty involved. A new methodology should base on linguistic variable. That methodology should give answer for following questions: how long the design process to stay and haw mach it will cost? And also it should help in optimization of design process. In those article was presented chosen tools like neural network and fuzzy sets, which can be used for develop e new method of modeling engineering design process.

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