Risk, neural network, project scheduling

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APPLICATION OF ARTIFICIAL INTELLIGENCE IN PROJECT MANAGEMENT UNDER RISK CONDITION

Abstract

Risk management problem was shown in the paper. Relationship between risk management and production process scheduling was analyzed. Different types of data analysis were presented. Toothed gear production process was taken as an example of task timing estimation.

1. PROJECT MANAGEMENT APPROACH

1.1. Introduction

Enterprises still face new challenges. In the global market competition is very strong. Enterprises are still looking for new products or try to modify existing ones. But wrong decision concerning new contracts could cause business failure especially for small or middle-sized enterprises. Many industrial managers ask how risky the new contract is and how much time and money should be devoted to realize that contract.

So, it is necessary to develop project management methods. Project management is a discipline of planning, organizing and managing resources to bring about successful completion of specific project goals and objectives. [1].

Five most relevant topics within project management include [20]:

- scope management
- time management
- cost management
- quality management
- risk management

During project execution unexpected events could happen which cause additional costs and time. So, risk management is an important part of project management. Risk is defined as a possible event or circumstance that can have negative influences on the enterprise and the results of the project.

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Project development of a product will have the same major stages (concept based on [26]):

- Initiation
- Planning and design
- Production (execution)
- Monitoring and controlling
- Closing

In the initiation stage the following areas are especially important: analyzing customer needs, review of the current offer – looking for similar products, conceptual design of the final product operation, project analysis including costs, tasks, deliverables, and schedule.

After the initiation stage, the product and system is designed. Occasionally, a small prototype of the final product is built and tested. Testing is generally performed by a combination of testers and end users, and can occur after the prototype is built or concurrently. Controls should be in place that ensure that the final product will meet the specifications of the project charter. The results of the design stage should include a product design that satisfies the customer needs and business requirements.

The execution process involves coordinating people and resources, as well as integrating and performing the activities of the project in accordance with the project management plan. The deliverables are produced as outputs from the processes performed as defined in the project management plan.

Monitoring and Controlling consist of those processes performed to observe project execution, so that potential problems can be identified in a timely manner and corrective action can be taken, when necessary, to control the execution of the project. The key benefit is that project performance is observed and measured regularly to identify variances from the project management plan.

Closing includes the formal acceptance of the project and the ending thereof.

1.2. Project scheduling

Tools popularly used for the project scheduling include the Gantt chart and the PERT/CPM chart [15,16,22].

Standard project management techniques like PERT/CPM are not able to consider iteration or feedback, where tasks may have to be reworked. So it is necessary to develop techniques to model iteration and help understand iterative development processes. [2]

A more comprehensive technique is signal flow graph which takes risk into consideration. Signal flow graph, a transform based method of describing networks algebraically, overcomes some of the limitations of PERT analysis. In principle, signal flow graph analysis can characterize the distribution of project completion time taking into account activity iteration and probabilistic looping. [1]

The signal flow graph [2] is a well-known tool for circuit and systems analysis in electrical engineering and for modeling discrete event systems. It begins as a diagram of relationships among a number of variables. When these relationships are linear, the graph represents a system of simultaneous linear algebraic equations.

The signal flow graph is composed of a network of directed branches which connect at the nodes. A branch *jk*, beginning at node *j* and terminating at node *k*, indicates its direction from *j* to k by an arrowhead on the branch. Each branch jk has a quantity associated with it, known as the branch transmission P_{jk}.

The branches represent the tasks being worked (an activity-on-arc representation) and the branch transmissions include the probability and time to execute the task represented by the branch.

The graph transmission is the sum of the path transmissions of all the possible paths between two given nodes. (fig.1) In particular, we are interested in computing the graph transmission from the start to finish nodes. The graph transmission can be derived using the standard operations for signal flow graphs. [2].

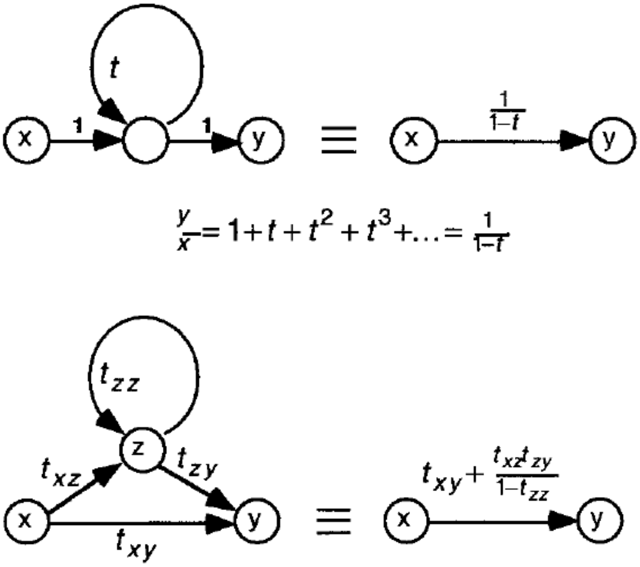


Fig.1. Absorption of a node in signal graph flow [2]

Eppinger and co. [2] described results of using signal graph flow in engineering design. Signal Flow Graphs model predicts the process lead time with disappointing accuracy (41% low). Eppinger indicated potential sources of error as incorrect modeling assumptions and imprecise data collection methods. Task timing and probabilities of iteration were inferred from interviews with engineers working on the project, and it is possible that their time estimates were optimistic and/or they underestimated the occurrence of iteration.

So, it is necessary to develop methods of data acquisition for project scheduling.

2. TASK TIMING ESTIMATION USING NEURAL NETWORKS

2.1. Neural Network - general information

Artificial neural networks are modern analytical tools, allowing for data processing based on the principle of human brain. Neural networks may be considered as a model of unknown characteristic, thus a system of mutually connected elements processing the data (neurons). Weighing elements are assigned to element connections and they determine the strength of these connections defined in a learning process. The phase of learning and the phase of reaction to specific stimulus can be distinguished in their performance. The model of solving the specific problem is being built during the learning process – absorbing the knowledge on the basis of presented examples. It is not necessary to determine the way of solving the problem; it is sufficient to collect large enough and representative sample population. Neural networks are a specific modelling technique, capable of representing complex relations. Considering neural networks from the point of view of algorithms applied, the following alternatives can be distinguished:

- Supervised learning: the learning data contains the characteristics of input signals and system reactions. Network learning consists of a selection of weighing elements such that network reaction to stimulus corresponds to reaction of a real system with highest precision;
- Unsupervised learning – consists of delivering input data to the network without information about the reaction to specific stimulus; the network itself analyses the relations among the input data.

The network architecture has to be determined before it is applied as a tool to data analysis. Neural networks can be:

- Unidirectional – where the signal is transferred to input layer, than across the hidden layers to output layer, without the recurrent reverse connections;
- Recurrent – in these networks the existing of cycles is acceptable; the output signal can be transferred to input;
- Cellular – where neurons are connected within the neighbourhood.

Over 80% of all applications of neural networks are related to so called multi layer networks, learning by back-propagation algorithm.

2.2. Application of neural network to determination of task timing

Neural network can be applied for task timing estimation in both the designing and the manufacturing phase of product development project. The results of research was published [10,12]

Basing on the research we can conclude that neural networks are promising in regard to possibility of constructing models which reflect the design and manufacturing process and estimate task timing. [14] To create those models it is necessary to collect data related to products designed and manufactured in advance (fig.2).

The experimental part of research consisted of numerical experiments, which allowed for determining process properties with decisive effect on learning results of neural network and selection of network structure leading to satisfactory learning results. The sensitivity analysis of the input data enabled to estimate the significance of features important for network learning process.

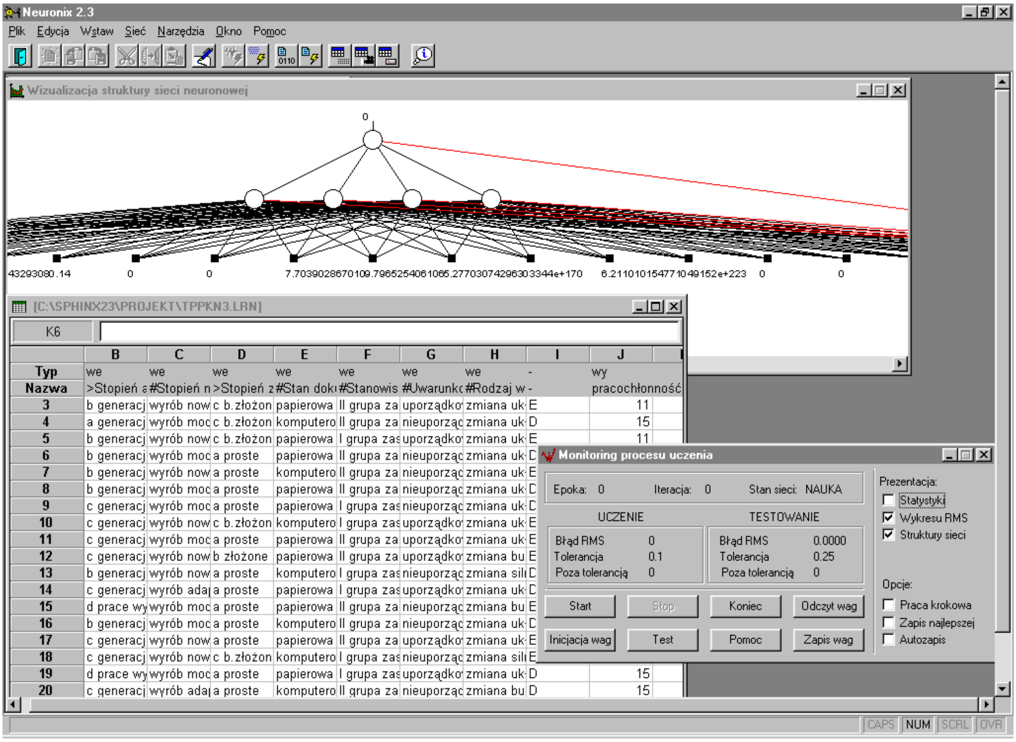


Fig.2. Time consumption of activity obtained using neural network

The data used in this analysis was taken from production practice of an enterprise having many years of experience in designing and manufacturing gearboxes.

The research aimed to design the architecture of a neural network and to construct the learning set. Determination of properties which would allow in the future to define the time requirement for the design process of toothed gear was of particular interest.

The network output has been set by the time of the design process of modernized gearbox.

In the manufacture process the neural network can be applied for time consumption prediction for a group of similar elements, for which the same framework machining is applied.

In small lot production, the machine setup parameters (speed, feed, and depth of cut) are set by an operator who works on the machine tool. The operator, basing on the technical documentation (dimension, accuracy class, surface quality) and his experience, sets the machine parameters. In the case study presented in the article accuracy classes, surface quality and tools used for machining were the same.
The use of a neural network for time per unit prediction can be applied in enterprises, in which feature of the input vector is simple in determination of a new product before the manufacturing process and registering in the IT system.

Because of many features taken into consideration in determining time consumption, neural network gives opportunities to successful use in the process of production modelling. It is necessary to accumulate a lot of data about a process and basing on this, to find the proper input feature vector and the proper topology of neural network.

3. PROJECT RISK MANAGEMENT

Another type of data necessary to project scheduling in signal flow graph is failure and rework information related to project looping. Prediction of failures is a part of enterprise risk management. Risk management is a systematic process of planning, identifying, analyzing, responding to, and monitoring project risks [8,9]. It involves processes, tools, and techniques that will help the project manager maximize the probability and results of positive events and minimize the probability and consequences of adverse events as indicated and appropriate within the context of risk to the overall project objectives of cost, time, scope and quality. Project risk management is most effective when first performed early in the life of the project and is a continuing responsibility throughout the project's life cycle. [8,9]

The risk management plan includes:

- methodology, roles and responsibilities,
- budgeting,
- timing,
- risk categories,
- definitions of risk probability and impact,
- probability and impact matrix,
- reporting formats,
- tracking.

In risk analysis we can use two methods of risk analysis: qualitative and quantitative. Qualitative risk analysis assesses the probability and the consequences (impact) of each identified risk to determine its overall importance. Using these tools helps to correct biases that are often presented in a project plan. In particular, careful and objective definitions of different levels of probability and impact are the keys to the credibility of the results.

The second method of risk analysis is quantitative risk analysis. Quantitative risk analysis is a way of numerically estimating the probability that a project will meet its cost and time objectives. Quantitative analysis is based on a simultaneous evaluation of the impact of all identified and quantified risks. The result is a probability distribution of the project's cost and completion date based on the identified risks in the project. Quantitative risk analysis involves statistical techniques, primarily Monte Carlo simulations that are most widely and easily used with specialized software. [4,9]

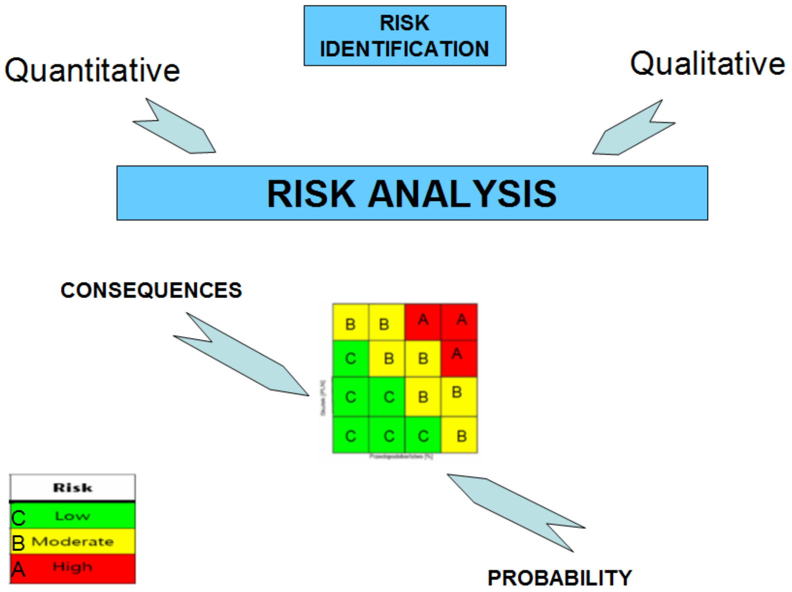


Fig.3. Risk analysis

The risk scores shown in the Risk Register for each objective reflect the PxI matrix chosen for the impact on that particular objective. In the Risk Register the risks can then be displayed by high, moderate, and low groupings for each of the four objectives (time, cost, scope, quality) and for threats as well as opportunities (fig.3). Department project managers often use the PxI matrices shown above, but they can set up a different matrix and assign different scores if it would better suit the project. [4,8,9]

Some Department project managers use a PxI matrix based on narrative probabilities and impacts (very low, low, moderate, high, very high) rather than numerical ones.

So an important questions is; which method of risk assessment is easier to use and more reliable? Consequently, it seems useful to compare different methods of risk analysis.

Risk identification helps to decide about:
Which risky situation should be mitigated,
How much time we need to realize the contract even it something goes wrong,
How much money we spend to do that contract.

The idea of applying data fixed during risk analysis to project scheduling was presented on fig. 4.

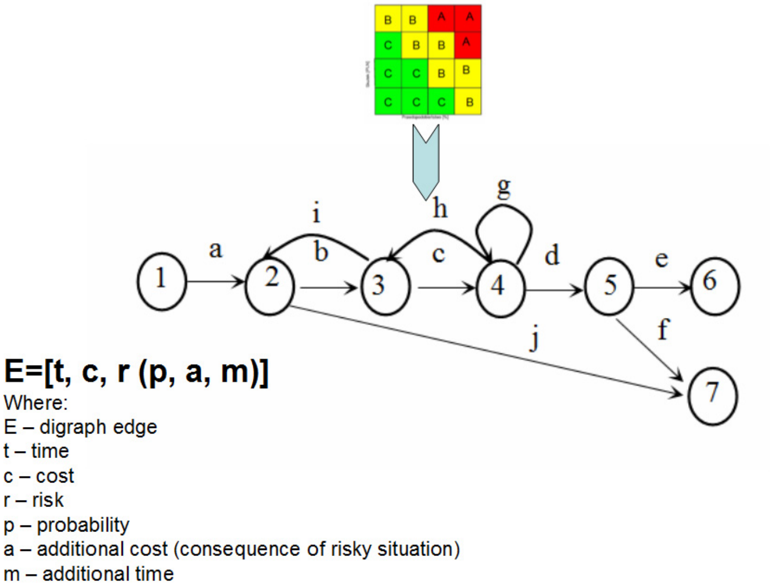


Fig.4. Application of data fixed during risk analysis to project scheduling

During risk analysis data can be fixed numerically or linguistically (fig.5).

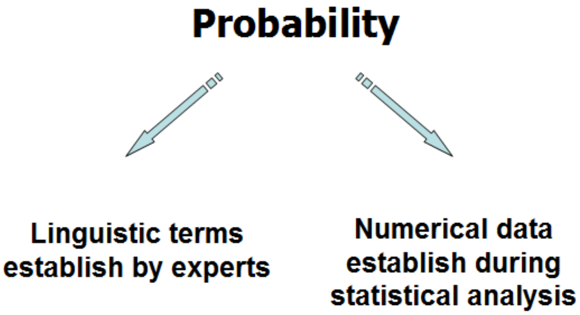


Fig.5. Data set during risk analysis

So, it will be interesting and useful to compare methods planning making use of these two kinds of data.

Therefore, it seems useful to elaborate on methodology of project scheduling based on linguistic terms concerning risk analysis. In particular, probability distribution may be described in words as likely, unlikely,... that we can use linguistic statements involved type-2 fuzzy logic, which input uncertainty.

It can happen that different experts have different opinions about probability of events. So it will be useful to apply fuzzy sets type-2. Type-2 fuzzy sets are „fuzzy fuzzy" sets which are three-dimensional and more expressive.

Zadeh introduced the concept of a type-2 fuzzy set in 1975. Type-2 fuzzy sets are an extension of type-1 fuzzy sets with an additional dimension (they are three-dimensional) that represents the uncertainty about the degrees of membership [14].

Discrete Membership function is a function of two variables.(fig.5)

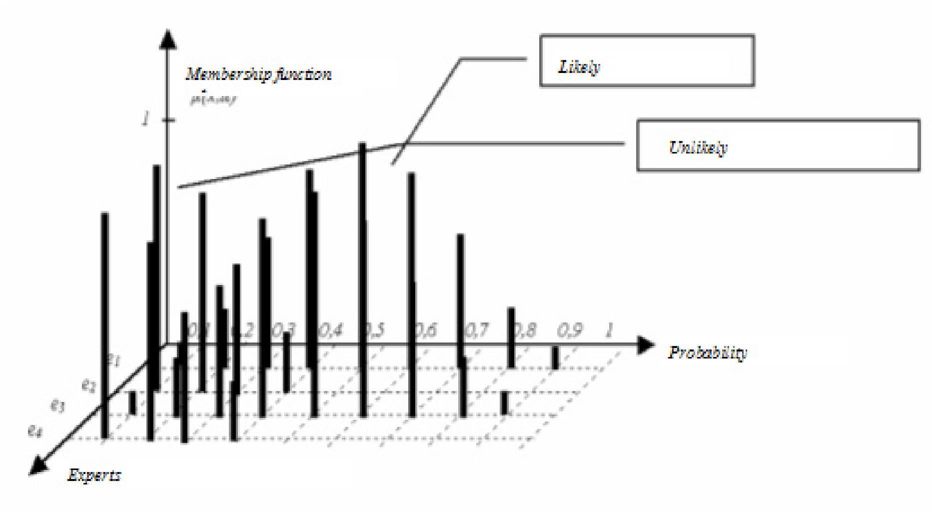
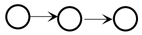
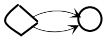
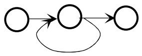
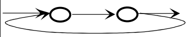
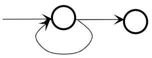


Fig.6. Discrete Membership function of two variables

In a classical flow graph we have to compute graph transmissions from the start to the finish node according to the rules presented on fig.1.

But application of linguistic terms with fuzzy sets type 2 required developing this computing method (tab.1).

Tab.1. Absorption of node in signal fuzzy graph flow

	Probability of graph transmission	Probability of graph transmission (Probability as a linguistic variable)
	$p_e = p_a p_b$	$\mu_E = \mu_{A\cap B}(x) = \mu_A(x) \cap \mu_B(x) = \sum_i (f(u_i)/u_i) \cap \sum_j (g(w_j)/w_j) = \sum_{i,j} (f(u_i) \wedge g(w_j))/(u_i \wedge w_j)$ oraz $u_i \wedge w_j \leq 1$
	$p_e = p_a + p_b$	$\mu_E = \mu_{A\cup B}(x) = \mu_A(x) \cup \mu_B(x) = \sum_i (f(u_i)/u_i) \cup \sum_j (g(w_j)/w_j) = \sum_{i,j} (f(u_i) \wedge g(w_j))/(u_i \vee w_j)$ oraz $u_i \vee w_j \leq 1$
	$p_e = \frac{p_a \cdot p_c}{1 - p_b}$	$\mu_E = \mu_{(A\cap C)/(1-B)}(x) = (\mu_A(x) \cap \mu_C(x))/(1 - \mu_B(x)) = \sum_{i,j,k} (f(u_i) \wedge g(w_j) \wedge h(x_k))/((u_i \wedge x_k)/(1 - w_j))$ oraz $(u_i \wedge x_k)/(1 - w_j) \leq 1$
	$p_e = \frac{p_a}{1 - p_a p_b}$	$\mu_E = \mu_{(A)/(1-A\wedge B)}(x) = \mu_A(x)/(1 - \mu_A(x) \cap \mu_B(x)) = \sum_{i,j,k} (f(u_i) \wedge g(w_j))/(u_i/(1 - w_j \wedge u_i))$ oraz $u_i/(1 - w_j \wedge u_i) \leq 1$
	$p_e = \frac{p_b}{1 - p_a}$	$\mu_E = \mu_{B/(1-A)}(x) = \mu_B(x)/(1 - \mu_A(x)) = \sum_{i,j,k} (f(u_i) \wedge g(w_j))/(w_j/(1 - u_i))$ oraz $w_j/(1 - u_i) \leq 1$

The output of network analysis of a project is probability distribution of successful project termination and time and cost interval related to project realization (fig.7). Results of research in this area were presented in [14].

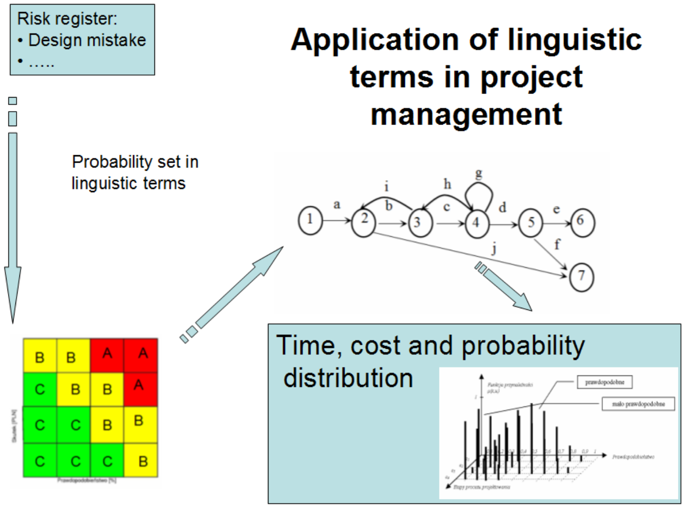


Fig.7. Application of linguistic terms in project management

4. CONCLUSIONS

Signal flow graphs provide a powerful, flexible modeling tool for the purpose of analysing product development processes. The modeling method allows for the modeling of dynamically changing design and manufacturing conditions concerning output of quantitative and qualitative risk analysis. The model can be used to compute the distribution of project durations and can easily predict the influence of chosen risk factures on it. The model also provides other information regarding the iterative structure of the project.

The model helps engineering managers to analyze a variety of scenarios, i.e evaluation of alternative project structure (benefits of different software application, the effects of co-location of teams working on strongly connected sub-problems, the effects of shortening or eliminating a step in the process: eliminating a prototyping or analysis step, or building and testing a prototype before the engineering analysis, etc.[2]). Knowing the variance of the lead time distribution can aid in understanding the magnitude of schedule risk involved, as well as likelihood and range of project slippage.

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