Methodology for assessing the construction of machine elements using neural models and antipatterns

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Abstract

This research proves the usefulness of applying antipatterns and neural networks as support during design of machine parts. This conclusion arises from construction of a negative quality reference, that allows to greatly reduce the solution space of bad mechanical part designs, without limiting the set of correct solutions.

The outcomes of this research enable implementation of software applications and modules, allowing use of antipatterns and neural models to support the process of designing machine parts. Main benefit arising from implementing the proposed method is the reduction of time required to detect a mistake in the design of a mechanical construction. Additionally, a widespread application of the antipattern concept provides several, global benefits through the symbolic representation of constructor's knowledge in antipatterns. Information about antipattern features of mechanical parts contained in a symbolic, analytical form, allows to detect mistakes early and systematically eliminate large amounts of errors in mechanical designs.

Published articles (seven in English and one in Polish) describe the definition of antipatterns, their applications in assessment of machine constructions, and promote created symbolical language KXML - used to represent constructor's knowledge. Therefore, the scientific fundamentals for analysing the role and ability to apply antipatterns have been created.

In the doctoral dissertation, the 1st chapter points out the observations and conclusions from the analysis of literature (141 positions) in the scope of: interactive machine design processes; numerical methods and their applications in comparative analysis; issues and problems of quality assessment.

The 2nd chapter defines the goal of the research work, scientific problems that have to be solved, defined theses, and a description of key assumptions and factors defining conducted research. It also defines the scope and expected results of the research work.

The 3rd chapter summarizes conducted theoretical analysis: defining the concept of the antipattern; classification model for elementary parts of the constructions, and highlights the key features and limitations of existing data representation formats.

The 4th chapter describes the method of identifying antipatterns and presents the first in the world set of antipattern mechanical constructions containing 17 antipatterns described lexically, using technical drawings, and a symbolic representation.

The 5th chapter describes the created method of symbolic representation of construction's features; the syntax of the KXML language - keywords, structure, method for representing relations and construction's features; a method for processing the data stored in KXML format.

The 6th chapter describes the created method of intelligent quality assessment of mechanical designs, in particular the approach to the normalisation of feature and structural data.

The 7th chapter contains a review of key factors and capabilities of numerical analysis of construction's features using numerical models selected for the research: summation (Antipattern Matching Factor, possibly enhanced with multiplication); algorithmic: modified Hamming distance and Kohonen maps; neural networks (probabilistic and convolutional).

The 8th chapter highlights the findings and conclusions arising from conducted research. It is important to emphasize that the techniques introduced in modern neural models (i.e. ConvNet, CapsNet) allow for automated data analysis using some of the structural information present in the symbolic representation - KXML. It also describes the limitations of created methodology (lack of ability to confirm the correctness of the construction) and the benefits arising from a substantial increase in the ability to transfer and preserve the knowledge of a human constructor by using KXML to create a library of antipatterns.