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S15 Soft computing

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SHAPE OPTIMIZATION OF THE MUFFLER SHIELD WITH REGARD TO STRENGTH PROPERTIES

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The exhaust system for an internal combustion engine of a vehicle consists of many components that must meet the appropriate requirements. One component of this system that has significant practical importance is the muffler shield The ability to form and adapt to the covered surface makes them very popular in the insulation of catalytic converters or whole components of the exhaust system, which are mounted directly behind the engine, in the so-called hot part of the system. The role of this part has evolved considerably in recent years, from a role purely protecting elements surrounding the system to elements from which additional criteria are required. Properly designed muffler shields must meet many criteria related to their strength characteristics, thermal, acoustic, etc. They are usually made of heat-resistant and thin sheet metal, whose thickness varies from 0.25mm to as much as 2.5mm. Shields are often made of aluminum, aluminum alloys, or some composites, with a ceramic heat-insulating coating to improve thermal insulation. These types of covers are bolted or welded to the components to be insulated. In this work, a geometric and numerical model of the shield was created in the form of a surface of appropriate shape with embossing and mounting holes. The position and shape of the embossments were parameterized and the proper optimization criteria depending on the stiffness of the system and equivalent stresses were proposed and implemented. FEM numerical model was prepared using Ansys software preprocessor. Optimization tasks were performed using multi-criteria optimization algorithms built-in Ansys software and additionally using external optimization in-house algorithms based on evolutionary methods. To perform the optimization task using an external program, appropriate additional procedures and script codes were developed. The developed codes in APDL and Iron Python language enable the construction of the parametric model in geometric module and numerical FEA analysis. Both approaches were tested and compared with regard to the quality of the obtained sets of Pareto-optimal solutions.

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IDENTIFICATION OF THERMOPHYSICAL PARAMETERS USING AN ARTIFICIAL IMMUNE SYSTEM

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The article concerns the identification of thermophysical parameters occurring in the hyperbolic two-temperature model. This model describes the heating of a thin metal film under the influence of ultra-fast laser pulses. It consists of two differential equations coupled with the electron-phonon coupling factor G. The first equation concerns electrons temperatures and the second one concerns lattice temperatures. Additionally, the model is supplemented with appropriate boundary conditions and an initial condition. The direct problem was solved using the finite difference method with a straggered grid. For even nodes, temperatures were determined, and for odd nodes, heat fluxes. The artificial immune system (AIS) is used in optimization procedure.
The AIS is a computational adaptive system inspired by the principles, processes and mechanisms of biological immune systems. In this algorithm of AIS, mechanism of clonal selection was used. In the first step of the algorithm the best matched antibody should be selected using parameter of clonal expansion and next these antibodies are multiplicated proportion to their degree of fit. Hypermutation is the next parameter which was used in AIS and which decided about diversity of population of solutions. Multiplied clones should be transformed in the special way so as to have achieved a better degree of adaptability than their predecessors. The other parameter which decided about diversity of population is crowding mechanism. Using this mechanism similar memory cells are removed and new memory cells are created randomly in the domain [1].
The aim of identification using artificial immune system is to estimate the values of thermophysical parameters occurring in the hyperbolic two-temperature model, where a thin metal film was subjected to laser pulses. Additionally the results of the direct problem were compared with the results of the experiment [2].

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CONVOLUTIONAL NEURAL NETWORKS IN THE SSI ANALYSIS FOR MINE-INDUCED VIBRATIONS

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Deep neural networks (DNN) have become one of the most often using soft computational tools for numerical analysis recently. By using the computational capabilities of graphics processing units (GPUs), these methods allow for quick processing of large amounts of data, which makes them an effective instrument e.g. in image and speech processing.

The huge success of DNN in the field of image processing is associated with the use of convolutional neural networks (CNN), which, thanks to their characteristic structure, allow for effective multi-layer features extraction. They make image classification and object detection efficient and accurate. In addition, compared to classical (shallow) fully connected neural networks (SNN) with a similar number of neurons, they generate less training parameters, which significantly reduces the learning time.

Another advantage of using convolutional neural networks is the possibility of applying machine learning technique calls transfer learning, which let to adapt a model trained on one task to solve the other one. It is especially helpful in the case of a small data set, what is usually common for experimental measurements.

In this paper, application of convolutional neural networks in one of the important soil-structure interaction (SSI) problems, i.e. the analysis of mine-induced vibrations transmission from the free-field next to the building to the building foundation is presented.

To do so, small data set from experimental measurements in-situ, containing less than 500 ground acceleration 1D records, was converted to 2D spectrogram images using Fourier transform and use as input to pre-trained CNN. As the output, ratio ra as a fraction of maximal values (amplitudes) of vibrations recorded at the same time on the building foundation (afmax) and on the ground (agmax) is expected. Therefore the last layer of convolutional neural network had to be changed from classification to regression one.

The obtained results indicate the suitability of CNN in the analysed problem. The possibility of using pre-trained deep neural network architecture, even in the case of such small input data set, might be an alternative to classical (shallow) fully connected neural network.

IDENTIFICATION OF NON-LINEAR BOLTED JOINT STIFFNESS USING TIGHTENING CHARACTERISTIC

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Bolted joints are one of the most critical and popular connections in mechanical engineering. The quality and safety of mechanical devices are related to the quality of bolted joint assembly processes. The automotive industry requires fast and reliable processes in semi- or full-automatic regimes. The modern tools used in assembly processes allow measuring the so-called tightening characteristic. It describes the relations between torque and the bolt head or nut rotation angles. Measurements in industrial conditions give noisy values of both variables. Therefore, it requires special attention during modelling. The destructive test produces a non-linear characteristic with three ranges relating to the following phases: the alignment phase, linear-elastic and plastic. The stiffness of the bolted joint can be defined as a derivative of the tightening characteristic with respect to the bolt head or nut rotation angle. The stiffness curve is helpful to identify the following indicators of the assembly process quality: the torque for the end of the alignment phase, the yield torque and the corresponding yield angle, and the stiffness of the joint in the linear-elastic regime.
Measurement errors make the task of determining the stiffness of the bolted joint ill-posed in the sense of the Hadamard. In the present work, the regularisation procedure will be formulated, and the identification problem will be expressed as an optimisation one. Two approaches are planned: the classical Tikhonov regularisation with the L2 norm and the total variation regularisation, which requires the L1 norm. Due to the character of the measured noisy data, the tightening characteristic should be modelled as an implicit parametric curve. Such a problem requires the modification of the L2 norm criterion; also, the regularised L1 norm term should be treated in a specific manner due to the non-differentiability (in the classical sense) of the absolute value function. The simple approach proposed in work introduces the new parameter, which could be included in the optimisation problem. The soft computing method will be applied to effectively solve the optimisation problem for optimal regularisation and the curve parameters. The harmony search algorithm will be apllied to solve the optimisation problem in the present work. The proposed algorithm is the global optimisation heuristic approach based on the improvisation process in music. It requires a small number of parameters and no knowledge about the derivative of the fitness function.
The examples will show the application of the proposed methods for real industrial data obtained during experiments carried out in the automotive industry's serial production conditions.

DIFFERENTIAL EVOLUTION AND ELEMENTS OF GAME THEORY FOR MULTI-OBJECTIVE OPTIMIZATION IN MECHANICS

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The problem of optimal design of mechanical systems for more than 3 criteria attract more and more attention in recent years. Such problems require efficient optimization algorithms as multiple numerical computations of objective functions for the mechanical problems are often extremely time-consuming and effective optimization methods have to be applied. In this research a novel algorithm was developed with improved convergence for a large number of criteria, employing an idea to couple game theory elements with a differential evolution algorithm. Game theory elements are used to compare solutions, each player to represent a single objective. Differential Evolution is a population-based evolutionary optimizer which in many variants found application in a range of engineering and scientific problems. The proposed algorithm is based on differential evolution and game theory paradigms. The suggested algorithm takes advantage of a game-theoretic cooperative approach and eliminates some drawbacks of other soft computing methods in the optimization of mechanical systems. The developed algorithm can be useful in a wide range of real-world multiobjective problems. The algorithm is comprehensively tested using introduced benchmark functions and performance metrics with comparison to other popular multi-objective optimization algorithms, such as NSGA-II and NSGA-III. A set of mathematical test functions exhibiting features distinctive of mechanical systems is utilized. The quality of results is assessed using a hypervolume indicator. Numerical examples of multi-objective optimization of selected mechanical systems are included. Functionals that represent real requirements asked of mechanical systems are proposed, formulated and numerically implemented. The boundary-value problem of a mechanical field was solved multiple times during optimization by way of the finite element method (FEM). Another important aspect is the representation of the multi-dimensional Pareto front and the selection of the interesting solutions when a large number of criteria is considered. The alternative method, compared to the traditional one, concerning the representation and selection compromise solutions, is proposed. The proposed method is aided by self-organizing maps (SOMs), which is one type of artificial neural network (ANN). Based on additional established preferences and using proposed visualization tools, a post-optimization decision-making process was aided resulting in a narrowed down set of solutions.

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DEEP LEARNING-BASED ANALYSIS AND OPTIMIZATION OF THIN-WALLED COMPOSITE SHELLS

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This paper presents single- and multi-criteria optimization of thin-walled composite axisymmetric shells. The variable parameters of the analyzed structures are the number of composite layers and lamination angles of the layers as well as the basic parameters describing the geometry of the analyzed structure. The analyzed data source describing the structure consists of natural vibration frequencies and vibration mode shapes, previously identified using a deep learning approach.
The identification of vibration mode shapes, i.e. determination of the mode shape family (circumferential, flexural, torsional, or axial), is carried out employing Convolutional Neural Networks. The use of the identification of the vibration mode shapes makes it possible to avoid the phenomenon of natural frequencies crossing, which causes many problems in tasks based on the analysis of natural frequencies performed without reference to the vibration modes associated with these frequencies. The identification procedure is very efficient, allowing the identification of the vibration mode shapes of the analyzed structure with different parameters describing the geometry and/or laminate layers.
The optimized parameters of the structure are the quantities related to dynamic properties of the analyzed structure (e.g. natural frequency, a width of gaps in the frequency spectrum of the structure), or to the ability of the structure to generate noise under external excitation. The response of the structure to the analyzed excitation is approximated in this research by a neural network-based metamodel. Therefore, the problem associated with the time-consuming calculations performed using the Finite Element Method (FEM) does not occur and evolutionary algorithms (namely Genetic Algorithms) can be easily applied to solve the optimization problem. The construction (learning) of the neural network-based metamodels still requires the results of the FEM simulations, nevertheless, the overall computational time is significantly less than the estimated time necessary to apply FEM during the main optimization problem.
The optimization task is defined either as a multi-criteria or single-criteria optimization problem (with a single objective function that is a linear combination of the objective functions used in multi-criteria optimization).
The proposed optimization algorithm is accurate, robust, and fast. The advantages of the proposed approach are related to the use of neural metamodels replacing the time-consuming finite element method and the use of genetic algorithms as the main optimization algorithm.

COMPARISON OF VARIOUS IMPROVEMENTS FOR EVOLUTIONARY ALGORITHM APPLIED TO LARGE OPTIMIZATION PROBLEMS

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The main objective of this long-term research is a significant improvement of Evolutionary Algorithms (EA) applied to a wide class of very large non-linear constrained optimization problems, including important engineering problems of computational mechanics. In particular, residual stress analysis in railroad rails, as well as the Physically Based Approximation (PBA) of experimental and/or numerical data, are taken into account. In the problems considered, a function given in the discrete form, e.g. expressed in terms of its nodal values, is sought. To obtain discrete formulation, any discretization method can be applied, including Meshless Finite Difference Methods used here. The EA are understood here as real-value coded Genetic Algorithms using three standard operators: selection, crossover, and mutation, as well as additional speed-up techniques, including: smoothing and balancing, a'posteriori solution error analysis and related techniques, adaptive step-by-step mesh refinement, estimaton of convergence point of population, and efficient constraint handling techniques. These general ideas can be applied in various ways. For instance, for solution smoothing two various approaches have been proposed - one of them is based on the Moving Weighted Least Squares technique, and the second one uses the fitness function enriched by introducing the mean solution curvature. Dedicated a'posteriori solution error analysis is based on the stochastic nature of the EA and weighted averaging of the best solutions taken from independent populations. The improved crossover, mutation, and selection operators take into account information about estimated local and global solution errors. Estimation of convergence point of population is a general technique, originally proposed for almost any population-based algorithm. We have proposed specific formulation and implementation of this technique for the EA-based approach. This research also includes searching of the most efficient combinations of all proposed techniques and their parameters. Parallel computations are used as well, but mostly as a support for new speed-up techniques. We discuss here the efficiency of all these speed-up techniques using simple but demanding benchmark problems, including residual stress analysis in chosen elastic-perfectly plastic bodies under various cyclic loadings. These benchmarks allow to choose almost any number of decision variables involved. The largest executed numerical tests involved more than 3000 decision variables. Chosen benchmark problems resulting from the PBA approach are considered as well. Numerical results obtained clearly indicate a possibility of practical application of the improved EA to the optimization problems considered. Each one of the acceleration techniques considered allowed for significant speed-up of computations. The overall acceleration factor up to about 140 times was reached. Numerical analysis also shows possibilities of further development of speed-up techniques considered.

MODELING OF ORDER BOOK WITH ORDERED FUZZY NUMBERS

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The stock market crashes over the past two decades have shown that the ability to find and estimate intraday liquidity in a fast and accurate way is extremely valuable, but also very challenging. A perfectly liquid market is one in which any amount of given security can be instantaneously converted into cash and back to securities at no cost. In the real world, a liquid market is one where the transaction costs associated with this conversion are minimized. Market liquidity is not unidimensional and can be understood in the following aspects: the number of securities that are traded (depth), the ability of the security prices to quickly recover after a liquidity shock (resiliency), the costs incurred in trading security (tightness), the time taken to execute a trade (immediacy), the intensity of trading volume impact on security prices (breadth). This paper aimed to investigate the possibility of using Ordered Fuzzy Numbers (OFN) to represent the order book at a given timestamp. The order book contains all buy and sell orders placed by investors, which are updated in real-time, for the most liquid securities, even several hundred times a minute. The order book is a table, so it is not possible to perform calculations directly on it. However, the ordered fuzzy number is a mathematical object (a pair of two functions) used to process imprecise and uncertain data and equipped with well-defined arithmetic. Converting the order book to an ordered fuzzy number allows the creation of time series of ordered fuzzy numbers (order books) and use them for further calculations, e.g. to represent and model the liquidity of a given financial instrument. The method of converting the order book to an ordered fuzzy number is developed and presented in this paper. An ordered fuzzy number defined in this way simply illustrates the depth of a given instrument, i.e. it shows how many shares we can sell or buy at a given moment and how it will affect the share price. At the same time, it is a well-defined mathematical object that we can use, for example, to define a liquidity measure and compare financial instruments with each other in relation to this measure.

MESHLESS METHODS AND A METAHEURISTIC FOR ELASTOPLASTIC PROPERTIES OF RODS IDENTIFICATION

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Among various numerical methods used in computational mechanics, one can distinguish a group of methods that don't have to generate a mesh of the considered domain before the main stage of computations. These methods are commonly known as meshless methods. Examples are the method of fundamental solutions and the global radial basis function collocation method, also called the Kansa method. Both methods have been successfully applied in the literature to solve various nonlinear boundary value problems.

On the other hand, recently, more and more popular optimization methods are metaheuristics. Their essential advantages are no need to give any initial potential solution, and they are derivative-free. In many cases, a source of inspiration for them is nature. A typical example is the genetic algorithm. However, in the literature one can find many other nature-inspired optimization algorithms, e.g., ant colony algorithm, chameleon swarm algorithm, forest optimization algorithm, etc. They have been applied with satisfactory results in various fields, e.g., economy, sport, computer vision, medicine, scheduling, etc. There is also a group of metaheuristics inspired by the natural behavior of viruses. One of them is the virus optimization algorithm.

In the paper, we solve the elastoplastic torsion problem numerically. Furthermore, we try to identify the elastoplastic properties of materials in the torsion test. The former is a direct problem. We consider a nonlinear boundary value problem, which is solved by the method of fundamental solutions and the global radial basis function collocation method. The latter is an inverse problem in which the elastoplastic properties of materials are unknown. To solve it, we treat it as an optimization problem. We define an error between the measurements from the torsional experiment and the results of simulations. To identify the parameters, we apply the virus optimization algorithm. The results show the excellent accuracy of the proposed approach.

ANOMALY DETECTION IN SCREW CONNECTIONS BASED ON GUIDED WAVES AND NEURAL NETWORKS

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Damage detection and identification is a challenge in many industrial applications. Civil engineering structures are an example of objects that are subjected to periodic or real time inspections. To reduce the cost and time needed for structures examination new measurements techniques and numerical methods for Structural Health Monitoring were investigated. In this article the problem of anomaly detection in screw connections was studied and in particular the loosening of bolts has become the center of attention. It is very important because such changes in connections between structural elements invluence the force distribution and in consequence can lead to a structure failure or even to its collapse. The laboratory model of two-storey and flat portal frame was examined. It was made of steel sections IPE 80 and each beam-to-column connection consisted of eight M8 bolts arranged in four rows. Various connection failure scenarios were simulated by loosening selected bolt rows. This led to the definition of seven different cases, including one reference (undamaged) scenario. A set of piezoelectric transducers was mounted to one of the transoms. They were used to actuate and measure guided waves propagating in the monitored structure. Laboratory tests allowed to collect patterns for different scenarios of anomalies in three single beam-to-column connections. Principal Components Analysis was used in order to decrease database dimensionality. Different types of classification tools (Shallow and Convolutional Neural Networks) were trained to build a diagnostic system for anomaly detection and identification of loose bolts rows. The obtained results were related to two series of experimental tests carried out on the same laboratory model. The analyzed strategies for selecting training patterns showed their influence to the accuracy of identification and the generalization abilities of the neural networks used. The article is complemented by a discussion on the planning of experiments with particular emphasis on the independence of data used to test diagnostic tools that use soft computational methods.

SOLVING DESIGN OPTIMIZATION PROBLEMS USING MACHINE LEARNING AND AUTOMATIC DIFFERENTIATION

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The paper deals with the application of modern machine learning models and automatic differentiation techniques for efficient solving of design optimization problems.

Machine learning is an ensemble of methods that are often applied for improving and speeding up the solutions of the design optimization problems.

Automatic differentiation is a set of techniques that are used for accurate evaluation of numerical derivatives of a mathematical function. The derivatives are expressed in a programming language.

In this context, machine learning and automatic differentiation offer flexible models for solving design optimization problems. For example, the feed-forward neural network models are used as the surrogate models to speed up the forward computations. Automatic differentiation can be applied for fast computing of derivatives of an objective function with respect to the design variables.

The aim of this work is to investigate some strategies of applying machine learning models and automatic differentiation for improving the design optimization process. The proposed solutions will be illustrated by several numerical examples.

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NEURAL MODELING IN PRACTICAL METRIC AGE ASSESSMENT OF CHILDREN AND ADOLESCENTS

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Artificial intelligence and neural modeling methods, as well as computer image analysis are nowadays a set of tools that are used to solve research problems in various fields and scientific disciplines. One of the application areas of neural image analysis is medicine and dentistry, where engineering-technology methods have been successfully applied. Imaging tests are widely used for diagnostic purposes because of their availability, non-invasiveness, and high quality. Due to the large number of patients and medical conditions, as well as the increasing lack of an adequate number of qualified medical personnel, there has been a need to automate the evaluation of radiological examinations. Metric age assessment is particularly useful for doctors to plan and evaluate the results of treatment, in anthropology and forensic medicine to determine the metric age of human remains, and to determine the age of children in the case of international adoptions or in individuals illegally staying in a given country. The analog methods used in the clinical assessment of the patient's chronological age, based on the development of his or her dentition, are subjective and characterized by low accuracy. These methods are not reliable because there are noticeable discrep-ancies between the chronological age and the predicted age determined using relevant scientifically developed tables, charts and atlases. This is the direct reason for the development of neural image analysis in the field of medical science. In the course of the conducted research, the possibility of using computer image analysis and neural modeling methods in the assessment of the metric age of children and adolescents from digital pantomographic images is presented. The analog methods curretntly used in the clinical assessment of the patient's chronological age are subjective and characterized by low accuracy. The result of the research is a set of 21 original indices necessary for chronological age estimation using computer image analysis and neural modeling, and nonlinear neural network models with up to 99% accuracy. The results of the conducted research are neural models that determine chronological age.

SIMULATIONS OF HIGH FREQUENCY WELDING BY USING INTEGRATED ELECTROMAGNETIC AND THERMAL MODELS FOR METAMODELS DESIGN AND IMPLEMENTATION

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Online monitoring of high frequency welding process is sophisticated task while it requires to trace parameters of production unit and externally installed sensors like pyrometers, high speed optical cameras or linear scanners. Moreover, the production process environment full of steam from heated cooling emulsion causes strong decrease of measurements accuracy. Thus, it is justified to create numerical model aiming at simulation of the process for various steel grades, product dimensions and process parameters to obtain reliable tool predicting final products quality. The results obtained from the model will allow to design and implement efficient metamodels reflecting dependency between process, materials and product quality. The poster presents idea of the whole approach as well as the progress of investigation including numerical aspects as well as material laboratory tests.

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APPLICATION OF FINITE ELEMENT METHOD BASED SIMULATIONS FOR PREDICTION OF LIQUID STEEL COOLING RATE IN MAIN LADLE FOR PURPOSES OF CYBER-PHYSICAL SYSTEMS

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Measurements of temperature distribution of liquid steel inside a ladle is very difficult or sometimes even impossible task in industrial conditions, due to the safety reason and high cost of equipment. On the other hand precise knowledge about the overheating level is crucial to maintain optimal range of temperatures during Continuous Steel Casting process to obtain the highest quality of casted billets. The poster presents solution of this problem by application of Finite Element based approach for prediction of steel cooling rate as well as possibilities of metamodel creation, which will be based on statistical dependencies between process parameters, material properties and temperatures. The usage of final model in Cyber-Physical System will be discussed.

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