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AUTOMATED SIMULATION-BASED WORKPLACE DESIGN THAT CONSIDERS ERGONOMICS AND PRODUCTIVITY

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Abstract
When designing a workplace with manual material handling tasks, it is important to consider both production and ergonomics. We developed an automated workplace design methodology that addresses production and ergonomics for tasks involving a handled mass of up to 23 kg. This process combines optimisation and a Digital Human Modelling (DHM) simulation, which yield the production and ergonomic measures. The task cycle time in current DHM simulations is based on Predetermined Motion Time Systems (PMTS). To address reservations about the time prediction accuracy of PMTS, we developed a new time prediction model that takes the influence of the handled mass into consideration. Our model and optimisation process were evaluated by using a case study of a box conveying workplace design. The time prediction model results did indeed agree with the real mass handling behaviour. Three design approaches (objective functions) were compared: considering only production, only ergonomics and both production and ergonomics. Each approach resulted in a different optimal solution. 40 refs.
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Key Words: *Workplace Design, Optimisation, Simulation, Ergonomics, Predetermined Time Prediction*

Pages 19-30

OPTIMIZATION OF WHEG ROBOT RUNNING WITH SIMULATION OF NEURO-FUZZY CONTROL

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Abstract
This paper presents laboratory simulator for wheel – legged (Wheg) robot running and application for collecting measurement data. Data is used as a basis for modelling and optimization of energy consumption of running Wheg. The laboratory setup includes instrumented measurement treadmill (IMT) and Wheg drive. The laboratory experimental setup also includes the sensors, drives and software application. Intelligent modelling and optimization of energy usage during Wheg's running is based on a combination of neural networks and genetic algorithms. Neural network has established a correlation between the parameters of running. Using genetic algorithm optimal parameters for running are found. Simulation of neuro-fuzzy control system for minimization of energy usage during running was developed as a function of the angle and Wheg running speed. 21 refs.
(Received in February 2016, accepted in October 2016. This paper was with the authors 2 months for 2 revisions.)

Key Words: *Instrumented Treadmill, Wheg, Neural Network, Genetic Algorithm, Neuro-Fuzzy Control*

Pages 31-44

A SIMULATION STUDY ON THE RECONSTRUCTION OF COALMINE VENTILATION SYSTEM BASED ON WIND RESISTANCE CORRECTION

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Abstract
To accurately correct wind resistance acquisition problems during the ventilation reconstruction and then calculate the air quantity in various roadways, taking the reconstruction of ventilation system in Shaqu Coal Mine of China as an example, the "calculation–feedback–correction" mechanism for adjusting roadway wind resistance was proposed based on the Ventsim simulation technique. Wind resistance was calculated and the change of air supply-demand after the reconstruction of the ventilation system was analysed using the proposed mechanism. The reasonable isolation reconstruction program was verified. Finally, the relationship between opening area of air window and wind resistance after the isolation reconstruction was fitted by the Fluent technology and the optimal opening area of air window was calculated. Results show that: (1) the ventilator area of the south upcast inclined shaft 1# operates unstably after the isolation reconstruction; (2) when the opening area of air window reaches at least 3.28 m^2, the ventilator works normally and steadily. The results also demonstrate that good ventilation effect can be achieved by adjusting resistance reduction and setting the optimal opening area of air window which conforms to the actual status of ventilation systems. 22 refs.
(Received in April 2016, accepted in November 2016. This paper was with the authors 2 months for 2 revisions.)

Key Words: *Mine Ventilation, Ventilation System Reconstruction, 3D Ventilation System Simulation, Feedback Mechanism, Air Flow Short-Circuit Method*

Pages 45-57

PRODUCT LIFECYCLE FORECASTING USING SYSTEM'S INDICATORS

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Abstract
The concept of product lifecycle is one of the tools of strategic management and gives a company the guidelines for marketing their product. It is very important that companies know in which lifecycle stage their product is. When conceiving a product platform, companies rely on the researches of socio-economic parameters. These parameters are called influence parameters, because by changing through time they influence the sales of the product and consequently the lifecycle curve, and require the company to change its business model, business strategy or their product. The changes of influence parameters reflect the changes of consumer needs, which is why in most cases the product needs to be adapted to the new parameters. In order for companies to know in which lifecycle stage the product is or will be, they often use forecasting methods. In this process, all the socio-economic parameters are projected that were valid in that specific period. The purpose of the article is to develop a model that takes into account the changing of influence parameters and gives reliable medium-term forecasts of the sales of a given product (attached is an example of a built-in oven lifecycle). 26 refs.
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Key Words: *Product Lifecycle, Simulation, Forecasting, Mathematical Modelling, System's Indicators*

Pages 58-71

A FUZZY HYBRID GA-PSO ALGORITHM FOR MULTI-OBJECTIVE AGV SCHEDULING IN FMS

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Abstract
An automated guided vehicle (AGV) is a mobile robot with remarkable industrial applicability for transporting materials within a manufacturing facility or a warehouse. AGV scheduling refers to the process of allocating AGVs to tasks, taking into account the cost and time of operations. Multi-objective scheduling is adopted in this study to acquire a more complex and combinatorial model in contrast with single objective practices. The model objectives are the makespan and number of AGVs minimization while considering the AGVs battery charge. A fuzzy hybrid GA-PSO (genetic algorithm – particle swarm optimization) algorithm was developed to optimize the model. Results have been compared with GA, PSO, and hybrid GA-PSO algorithms to explore the applicability of the algorithm developed. Model's feasibility and the algorithms' performance were investigated through a numerical example before and after the optimization. The model evaluation and validation was conducted through simulation via Flexsim software. The fuzzy hybrid GA-PSO surpassed the other methods, although obtaining less mean computational time was the only significant improvement over hybrid GA-PSO. 35 refs.
(Received in April 2016, accepted in October 2016. This paper was with the authors 2 months for 3 revisions.)

Key Words: *Automated Guided Vehicle, Scheduling, Multi-Objective Optimization, Genetic Algorithm, Particle Swarm Optimization, Fuzzy Hybrid GA-PSO*

Pages 72-83

NEURAL NETWORK AND TRAINING STRATEGY DESIGN FOR TRAIN DRIVERS' VIBRATION DOSE SIMULATION

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Abstract
Vibration can cause professional illnesses in train drivers, giving also rise to lawsuits to the employer. A possible cause may be the lack of systematic vibration estimation processes, due to operational complexities, subjectivities involved and the cost of dedicated tests. Estimation quality may be improved by using a driver seat model along with cabin floor vibration data acquired during the train dynamic approval tests. However, due to the nonlinearities present, analytical models frequently show inaccurate results. This work deals with the design of an appropriate neural network for predicting the seat-driver interface vibration, based on selected and processed cabin floor acceleration data obtained during the dynamic approval tests. Network type, input signals set and signal conditioning have considerable impact on the simulation accuracy. Results show good correlation between simulated and experimental data, even better between simulated and measured standard vibration dose indicators, being *RMS* errors between 3.9 % and 9.4 % and peak factor errors between 0.8 % and 9.6 %. 23 refs.
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Key Words: *Vibration Dose, Artificial Neural Network, Nonlinear Model, Train Engineer, Train Driver*

Pages 84-95

DYNAMIC ALLOCATION OF ADDITIONAL HUMAN RESOURCES USING HYBRID SIMULATION

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Abstract
This work simulated several alternatives for the dynamic allocation of additional human resources in a company that produces a group of specific products. The goal was to increase the average amount of the margin of the total contribution through a hybrid application of a discrete event simulation (DES) and an agent-based modelling simulation (ABMS). Two different decision-making forms were proposed to determine which workstation should receive an additional operator. The first proposal was based on the occupancy level of the operators, while the second one was based on the intermediate queue size. The computational model was operationally validated by comparing the results with actual production data from the company. Twelve scenarios were analysed using a margin of the established contribution. Based on the occupancy rate, the ratio improved on average by 27.68 %, with an additional operator in the workstation. According to the second criterion, this improvement raised to 117.51 %. 22 refs.
(Received in May 2016, accepted in October 2016. This paper was with the authors 1 month for 1 revision.)

Key Words: *Hybrid Simulation, Agent-Based Simulation, Discrete-Event Simulation, Resource Allocation, Food Production Process*

Pages 96-107

PARAMETRIC STUDY OF THROUGHPUT PERFORMANCE IN SBS/RS BASED ON SIMULATION

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Abstract
This paper presents an analysis of cycle times and throughput performances of Shuttle-Based Storage and Retrieval Systems (SBS/RSs), a relatively new technology that is becoming an important part of automated warehouses. A parametric simulation model was developed for the purposes of this research. The model enables calculation of Single Command (SC) and Dual Command (DC) cycle times and throughput performances of SBS/RS. The model was tested on a case study, which is based on a real type of SBS/RS. Experiments were designed to evaluate the following factors, such as number of bays n_x and minimum warehouse volume Q. Our research uses Design of Experiment (DOE) analysis and helps to achieve the proper dimension of the SBS/RS, which gives us the best possible performance of the SBS/RS. The simulation based on the presented model delivers the best SBS/RS designs. 28 refs.
(Received in May 2016, accepted in October 2016. This paper was with the authors 2 months for 1 revision.)

Key Words: *Logistics, Warehouses, Shuttle-Based Storage and Retrieval Systems, Simulation, Design of Experiments, Performance Analysis*

Pages 108-120

MODEL FOR SIMULATION OF LIFE CYCLE COSTS AT THE STAGE OF PRODUCT DEVELOPMENT

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Abstract
Managing the costs of a product life cycle, which is performed at the stage of its development, has a dominant influence on achieving and maintaining the competitiveness of the product in the market and the target profit as the primary production goal. Development is of crucial importance in the product life cycle, because evaluating individual solutions for the new product's conceptual and preliminary design based on the simulation of costs of all stages of its life cycle represents the way of ensuring the design requirements for excellence. This paper presents in detail the setting and development of a hybrid model of product life cycle cost management, based on fuzzy neural networks. 24 refs.
(Received in May 2016, accepted in August 2016. This paper was with the authors 1 month for 1 revision.)

Key Words: *Product, Product Life Cycle, Cost Simulation, Cost Management*

Pages 121-132

MESHING SIMULATION AND STRENGTH CALCULATION OF A CARBURIZED GEAR PAIR

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Abstract
The material in the carburized layer of a carburized gear is nonlinear. However, no systematic theory and method is available to analyse the strength of nonlinear materials; thus, calculating the exact strength of carburized gears is difficult. The traditional method of calculating the strength of carburized gears considered the material as uniform, which is susceptible to make errors. To address this problem, a hierarchical simulation method was proposed to calculate the strength of carburized gears. The strength calculation principle of carburized gears was first analysed. Then, a solid modelling method of carburized gears was presented based on the extraction technology of the layered homogeneous material. Finally, the meshing process of carburized gears was simulated, and the distribution and variation laws of the root, contact, and shear stresses during the meshing process were determined accurately. Results show that the shear stress of carburized gears initially increases and then decreases along with depth direction, and the maximum value appears in the surface below. However, the shear stress of non-carburized gears decreases linearly. The equivalent stress of the two kinds of gears decreases linearly with depth direction, whereas the decreasing amplitude of the carburized gears is larger than that of the non-carburized gears. A significant error in the calculation of the strength of carburized gears can be clearly observed using the traditional method. By selecting the appropriate parameters, the method proposed in this study can be used to simulate the meshing process of the carburized gear pair and calculate its strength accurately. 27 refs.
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Key Words: *Carburized Cylindrical Gears, Strength Analysis, Modelling, Transient Simulation Analysis*

Pages 133-144

OPTIMIZATION AND SIMULATION FOR AIRPORT EMERGENCY INVENTORY WITH REPLACEMENT

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Abstract
The paper assumes that the accident occurrence time is stochastic and emergency supplies is perishable, then two replacement stochastic models based on remaining lifetime and remaining quantity are first proposed. In order to identify the effectiveness of replacement strategy, two replacement-based stochastic models are compared with the general stochastic model that is non-replacement, measured by inventory level and total costs. A discrete-event simulation model is developed to demonstrate effects of occurrence time uncertainty, replacement ratios and distributed functions in occurrence time and demand. Sensitive analysis shows that the optimal decision is more sensitive to remaining quantity ratio as compared to remaining lifetime ratio. The paper shows that when decision-makers ignore occurrence time uncertainty and limited warehousing time, they may significantly miss better decisions. Further, simulation results demonstrate that different distributed functions in both occurrence time and demand lead to different inventory strategies. 30 refs.
(Received, processed and accepted by the Chinese Representative Office.)

Key Words: *Occurrence Time Uncertainty, Emergency Supplies, Replacement strategy, Inventory Optimization*

Pages 145-156

OPTIMAL SELECTION OF MOVABLE SHELVES UNDER *CARGO-TO-PERSON* PICKING MODE

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Abstract
In recent years, some e-commerce companies such as Amazon have adopted the cargo-to-person picking mode to improve their pickup efficiency. Under this mode, a shelf can store several types of goods and a type of goods can be placed on some shelves. When orders arrive, the warehouse robots move one shelf or more containing the ordered items to a fixed platform, and the pickers select the items from the shelves. It is very important to decide which shelves should be moved to increase picking efficiency. This paper addresses the problem of optimal movable-shelf selection for the cargo-to-person picking mode. The goal of this study is to minimize the total time (costs) of moving the selected shelves to finish a batch of orders. We model this problem using 0-1 linear programming and show that the problem is NP-hard. Furthermore, we propose a three-stage hybrid heuristic algorithm with polynomial complexity to solve it. We conduct numerical experiments to show the efficiency of this algorithm. 28 refs.
(Received, processed and accepted by the Chinese Representative Office.)

Key Words: *Cargo-to-Person Mode; Warehousing; 0-1 Linear Programming; Heuristic Algorithm*

Pages 157-166

MODELLING AND SIMULATION FOR PRODUCTION LOGISTICS SYSTEM IN INDUSTRIAL ENTERPRISES BASED ON HYBRID NETWORK

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Abstract
Modern industrial production logistics systems in a modern are very complicated, which generally includes many continuous variables and discrete events. For these complicated industrial production logistics systems, this paper has set up a new hybrid Petri network model based on the common hybrid Petri network and with a combination of differential Petri net and controlled Petri net. This paper made simulation calculation with Java language and studied the modelling object through an industrial DFM solvent recovery process, which has revealed that this model is suitable for the modelling and simulation of hybrid production logistics system in industrial enterprises and can unify the simulation and analysis under the framework of one model. Targeted control strategies can be proposed based on simulation results, which is of great significance in instructing and improving production efficiency. 22 refs.
(Received, processed and accepted by the Chinese Representative Office.)

Key Words: *Hybrid Petri Net, Production Logistics, Modelling, Simulation*

Pages 167-175

SIMULATION OF STEEL PRODUCTION LOGISTICS SYSTEM BASED ON MULTI-AGENTS

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Abstract
To deal with the complex structure and difficulty in precise expression of the interaction between entities in the steel production logistics system, this paper uses complex network theory and multi-agent system engineering to simulate the complex steel production logistics system, and thereby calculate related parameters, gather statistics, and optimize the steel production logistics system. According to the analysis, the processing of logistics is low in efficiency because 19 pieces of equipment are involved from the beginning of the logistics subject processing to the final formation of steel, while only a few processes are required for about half of the auxiliary material or auxiliary process. The system logistics is not compact because most of the equipment used in steel production has only a single function and a limited service area, whereas a higher degree distribution indicates a higher importance in a piece of equipment in the network. This is a must to guarantee the normal operation of the equipment with a higher degree distribution. The simulation results are basically the same with the actual production results, and the error is within the acceptable range, which proves that the simulation system is correct and effective. 21 refs.
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Key Words: *Production Logistics System, Complex Network, Multi-Agent System Engineering, Simulation, Steel Production*

Pages 176-186

NONHOLONOMIC MOTION PLANNING USING TRIGONOMETRIC SWITCH INPUTS

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Abstract
In this paper we present a local motion planning law called trigonometric switch inputs which can steer the chained form system to the final positions, at least locally, around the initial positions. This method steers the system step by step instead of steering all states in one step. The advantages of trigonometric switch inputs law are that the motion trajectories are quite smooth and have less oscillation and lower computational costs, all of which is beneficial for the application of the time scale transformation technique and improvement of motion efficiency of the system. A two-wheeled mobile robot system is steered by this new motion planning law to illustrate the practical application. Finally, simulations with the time scale transformation technique and experiments with the mobile robot verify the feasibility and effectiveness of trigonometric switch inputs law. 16 refs.
(Received, processed and accepted by the Chinese Representative Office.)

Key Words: *Chained Form Conversion, Motion Planning, Trigonometric Switch Input, Nonholonomic System, Time Scale Transformation*