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EFFECT OF HUMAN FACTOR PERFORMANCE ON THE PRODUCTIVITY OF A MANUAL ASSEMBLY LINE

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Abstract
To improve the reliability of the discrete event simulation model, it is necessary to represent, the best way possible, the operator behaviour and his subsequent performance. Deterministic simulation models often overestimate the production capacity of manufacturing systems since they don´t consider some key relationships, such as the impact of human factor performance on productivity. This paper, with the aid of statistical techniques, analyses the total of boards produced, taking into consideration different periods of work shifts to apprehend the variability of human performance at different points throughout the day. Therefore, this paper aims to investigate the impact of human performance on the work shift and, hence, on the computer model's validity. Results reveal that human performance has a significant impact on the productivity of the assembly line investigated and affected the reliability of production forecasts through stochastic simulation. 33 refs.
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Key Words: *Discrete Event Simulation, Human Factor Performance, Manual Assembly Line, Simulation Model Reliability*

Pages 375-386

DISCRETE EVENT-BASED RAILWAY SIMULATION MODEL FOR ECO-EFFICIENCY EVALUATION

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Abstract
Based on the discrete event-based simulation method, this paper aims to model the Paranaguá "KM5" Railyard, looking at the inbound and outbound movement of trains and wagons from an ecologic perspective. The originality of this paper comes from the inclusion of the train parameters and eco-efficiency concerning train operation. Moreover, it helps the operator to define a range of optional strategies for wagon classification, which would be more environmentally friendly, also providing a basis for further research on this theme. This research method is quantitative, based on visits to the railyard, interviews with rail operators, the original railyard's geometrical design, real operation charge for 2016, as well as theoretical studies. The main findings are that the analysis of the simulated cases can be applied by the rail manager to the railyard's operation manual. The implication for theory and practice is that the findings can also contribute, with different parameters of decision, not only the reduction of time taken but also with consideration of the environmental impact. 19 refs.
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Key Words: *Railyard, Discrete Event-Based, Simulation, Eco-Efficiency, Anylogic, Paranaguá*

Pages 387-398

INFLUENCE OF EA CONTROL PARAMETERS TO OPTIMIZATION PROCESS OF FJSSP PROBLEM

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Abstract
The ability of Evolution Algorithms (EA) to find an optimal solution is usually given by various algorithm operators. Population size and a maximal number of generations are usually set base on available timespan. Setting selection and elimination methods together with crossover probability are usually based on intuition and sometimes are problem specific. That is the reason presented research is focusing on the approach of how to set elimination methods and crossover probability by the statistical approach to eliminate the necessity of experience and intuition. This article describes the scheduling model together with the used EA to solve the Flexible Job Shop Scheduling Problem (FJSSP). Statistical process control methods are applied as there is a designed experiment to find out the statistical significance of each parameter during solving one of the FJSSP hardest problems. Crossover and elimination statistical importance are analysed and suitable levels of them are suggested. The statistical approach as a possible methodology to set the mentioned parameters is then discussed. 33 refs.
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Key Words: *Evolution Algorithms, Flexible Job Shop Scheduling Problem, Parameter Control, Statistical Process Control*

Pages 399-409

ATTITUDE ADJUSTMENT OF BACKFILLING SUPPORT BASED ON MECHANICAL-HYDRAULIC CO-SIMULATION

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Abstract
The attitude monitoring and controlling (AMC) technology of backfilling support is critical for the development of unmanned mining. However, the underground products need to meet the explosion-proof requirements, which made new AMC methods hard to be tested. To solve this problem, an AMC method was proposed, and the multi-software co-simulation technology was applied to study the automatic attitude adjustment behaviour of support. Firstly, the AMC mathematical model of the support was established. Secondly, the mechanical-hydraulic co-simulation (MHC) model was constructed using ADAMS and AMESim. The co-simulation model rationality was analysed by comparing various action sequences. Finally, by introducing an attitude calculator into the MHC model, the pose adjustment performance of the support was tested. Results show that the coupling action of the leg and equilibrium jack causes the support system vibration. The proposed AMC method can achieve the precise support attitude control. The cumulative leg action error is ± 0.3 mm, while that of the equilibrium jack is ± 2 mm. 25 refs.
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Key Words: *Backfilling Support, Attitude Adjustment, Vibration, Mechanical-Hydraulic Co-Simulation*

Pages 410-421

COMPARISON OF ADVANCED METHODS FOR PICKING PATH OPTIMIZATION: CASE STUDY OF DUAL-ZONE WAREHOUSE

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Abstract
Minimizing the travel distance of a picking tour is often considered an imperative factor in improving warehouse operation efficiency. This paper concentrates on the performance of the genetic algorithm (GA) method and its comparison to other routing strategies such as heuristics, the experienced warehouse picker and the brute-force algorithm under given assumptions. The set of simulations and calculations is based on an industrial case example. The results of the investigated routing strategies under given assumptions (middle size dual-zone warehouse, order size – 15 items, etc.) show the dominance of the brute-force algorithm in comparison to the experienced picker, GA and simple heuristics. It also indicates that GA is an optimization method which needs modification in dealing with picking path optimization problems and under given assumptions could generate better solutions than simple heuristics and comparable to experienced picker. The results also show quite significant sensitivity of GA results on used selection operator, size of population and number of generations. 26 refs.
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Key Words: *Picking Path, Optimization, Genetic Algorithm, Travel Distance, Routing Strategy*

Pages 422-433

REFLUX PROBLEM ANALYSIS AND STRUCTURE OPTIMIZATION OF THE SPIRAL GROOVED-WHEEL FERTILIZER APPARATUS

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Abstract
The spiral grooved-wheel fertilizer apparatus has a reflux problem during the fertilization process, it influences the fertilization uniformity. To improve the fertilization performance of the fertilizer apparatus, the reflux phenomenon and mechanism were analysed in this study. The reflux process of fertilizer particles was simulated with a discrete element software. The motion trail and stresses during the reflux process were analysed. A staggered spiral grooved-wheel was proposed, and the key parameters of the staggered spiral grooved-wheel were determined. Furthermore, a comparative study on the fertilization performance of the staggered spiral, spiral, and straight grooved-wheels was conducted through a bench test. The results show that the staggered grooved-wheel does not appear fertilizer reflux when the staggered length is $e_{max} = L / 6$. Under the same conditions, the staggered spiral grooved-wheel fertilizer apparatus shows the smallest variation rate of fertilization quantity, follows by those of the spiral and straight grooved-wheel fertilizer apparatuses, successively. Therefore, the staggered spiral grooved-wheel fertilizer apparatus shows the best fertilization uniformity under the premise of satisfactory fertilization quantities. 21 refs.
(Received in May 2020, accepted in August 2020. This paper was with the authors 2 months for 1 revision.)

Key Words: *Staggered Spiral Grooved-Wheel, Reflux Phenomenon, Fertilization Performances, Structural Optimization*

Pages 434-445

INTEGRATING INVENTORY AND TRANSPORT CAPACITY PLANNING IN A FOOD SUPPLY CHAIN

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Abstract
The general objective of this paper is to simulate a supply chain to assess the effects that different inventory management policies and transport capacity systems have on costs (transport) and service levels (stockouts). This paper specifically aimed to facilitate the decision-making process about planning distribution capacities, particularly when contracting a transport fleet in a supply chain under uncertainty with a 1-year time horizon by evaluating different types of scenarios, which vary depending on availability of vehicles and obtaining vehicles. The system dynamics simulation model was applied to a real-world food supply chain and can be adopted by chains related to diversified cropping systems. The results provide the best decision alternative in terms of costs and inventory levels by considering the transport capacity life cycle, the time to acquire additional transport capacity, the reorder point in days of stock and the target inventory. 35 refs.
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Key Words: *Supply Chain, Inventory Management, Transport Capacity Management, Food Sector, Simulation, System Dynamics*

Pages 446-457

GAME-BASED WORKSHOPS FOR THE WOOD SUPPLY CHAIN TO FACILITATE KNOWLEDGE TRANSFER

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Abstract
Knowledge transfer between science, industry and education is needed to manage complex wood supply chains challenged by increasingly frequent risk events and natural disturbances. Discrete event simulation provides a high potential for stakeholder participation, pedagogical purposes and decision support but simulation models for the wood supply chain are rarely used in industrial training and university education. Consequently, this paper showcases the further development of a scientific discrete event simulation model for the wood supply chain to an intuitively usable workshop edition focusing on game-based design, visualization and animation. Furthermore, a resulting guideline to develop workshop structures consisting of an input, learning by doing and analysing stage including learning objectives is delivered. Presented experiences and feedback of conducted scientific, industrial and educational workshops illustrate the facilitated knowledge transfer. Simplification, visualization and stakeholder collaboration increase model reliability and suitability enabling the dissemination of adapted scientific discrete event simulation models in game-based workshops to sensitize, train and provide decision support for managers, students and researchers. 35 refs.
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Key Words: *Discrete Event Simulation, Logistics, Wood-Based Industry, Decision Support System, Simulation Education; Workshop Design*

Pages 458-469

SIMULATION OF COST DRIVEN VALUE STREAM MAPPING

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Abstract
Value stream mapping (VSM) is based on an analysis of the times required to carry out production processes throughout the customer-manufacturer-supplier logistics chain. The goal of VSM is to identify wastes and eliminate them, thereby increasing the added value of a product. The paper presents an extension of the VSM concept which is based on determining the costs associated with the necessary operations and determining, based on said costs, the total costs of the entire production process. When eliminating those activities that represent waste, we can, by simulating the total costs, determine the contribution of the implemented measure to the reduction of lead time and, above all, the reduction of costs and thus the economic efficiency of the production process. For the presentation, by simulating the identified cost effects of the anticipated changes, we can calculate the leanness cost index and, using portfolio analysis of the leanness of the production system, analyse the effects. The application of the proposed methodology is shown in the case of transition from individual to lean and agile series production of ceramic capacitors. 19 refs.
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Key Words: *Lean Production, Value Stream Mapping (VSM), Simulation, Leanness Cost Index, Portfolio Analysis of Production System Leanness*

Pages 470-481

PRODUCTION EFFICIENCY EVALUATION AND PRODUCTS' QUALITY IMPROVEMENT USING SIMULATION

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Abstract
Every manufacturing company producing products of any kind is forced to constantly address the issue of improving the efficiency of its production lines, increasing their production capacity and last but not least, increasing the quality of products. Every physical intervention directly in the production process results in a change in the efficiency of this process. It may be a change for the better, but often such a change may not have the expected effect. Today's era of digital industrialization offers us the opportunity to verify possible changes in the production process without physically interfering with existing production, and thus it is also possible to verify the real consequences of the intervention. The present paper deals with improving the efficiency and quality of products in the production process in the food industry. It is the production of various types of packaged salads, cod and other types of fish. The aim of the paper is to test the possibility of improving the efficiency of the packaging line for food products as well as the possibility to improve their quality by applying sensors of foreign bodies of various kinds, which can sometimes get into salads. 21 refs.
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Key Words: *Simulation, Production Process, Efficiency, Quality*

Pages 482-493

S-N CURVE AND QUANTITATIVE RELATIONSHIP OF SINGLE-SPOT AND MULTI-SPOT WELDINGS

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Abstract
The relevant $\Delta F–N$ curves are fitted based on the experimental life and load of single-spot and multi-spot-welded specimens. To improve the correlation and universality of curves, a unified S-N curve is needed. The finite element model of spot welding is firstly established. The S-N curves of single-spot and multi-spot-welded specimens are thereafter obtained according to the fatigue life of spot-welded specimens and the corresponding equivalent structural stress calculated based on the Sheppard method. To improve the fitting effects of S-N curves with relatively low correlation coefficients, the structural stress formulae are optimized using three different optimization methods based on the quasi-Newton method. Finally, the quantitative relationship among the S-N curves of spot welding with different solder joints is deduced; the foregoing can provide reference for the prediction of fatigue life of multi-spot welding. 34 refs.
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Key Words: *Spot Welding, Quantitative Relationship, S-N Curve, Finite Element Method, Optimization*

Pages 494-504

MULTI-OBJECTIVE ENERGY-SAVING JOB-SHOP SCHEDULING BASED ON IMPROVED NSGA-II

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Abstract
To pursue sustainable development, the manufacturing industry must meet strict requirements on energy-saving. However, the traditional manufacturing mode is not sufficiently green to satisfy such requirements. To solve the problem, this paper attempts to optimize the multi-objective energy-saving job-shop scheduling process. Firstly, a multi-objective optimization model was established to minimize the maximum makespan, total carbon emissions, and total tardiness. Then, the non-dominated sorting genetic algorithm II (NSGA-II) was improved to provide a solution to the multi-objective energy-saving job-shop scheduling problem (JSP). Finally, the effectiveness of the improved NSGA-II for solving the said problem was verified through simulation. The research provides a good reference for improving the greenness of manufacturing mode. 28 refs.
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Key Words: *Job-Shop Scheduling Problem (JSP), Multi-Objective Energy-Saving Optimization, Non-Dominated Sorting Genetic Algorithm II (NSGA-II), Green Manufacturing*

Pages 505-516

ENERGY-SAVING CLOUD WORKFLOW SCHEDULING BASED ON OPTIMISTIC COST TABLE

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Abstract
In recent years, intelligent flow sensors have been applied to many fields. Cloud operation is a design method to further improve the intelligence of such sensors. However, the cloud workflows of intelligent flow sensors consume too much energy, making it imperative to schedule cloud workflows. With the growing awareness of energy conservation, it is a hot topic to design an energy-efficient workflow scheduling algorithm. Therefore, this paper puts forward the predict minimum energy consumption (PMEC) algorithm, a cloud workflow scheduling algorithm that strikes a balance between energy consumption and execution time. Firstly, the optimistic cost table (OCT) was adopted to rank the tasks by priority. Then, the resources, i.e. virtual machines, were assigned statically to the tasks, in the light of task priority and energy consumption. After that, the workflow was scheduled according to the assignments. Simulation results show that the PMEC is much more energy efficient than traditional list-based scheduling algorithms. 25 refs.
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Key Words: *Energy Consumption, Workflows, Scheduling Algorithm, Sensors*

Pages 517-528

A DISCRETE JOB-SHOP SCHEDULING ALGORITHM BASED ON IMPROVED GENETIC ALGORITHM

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Abstract
In a discrete job-shop, the scheduling objectives are often conflicting and constrained, and the actual production is disturbed by many uncertainties. This paper combines bi-directional scheduling with genetic algorithm (GA) to optimize the static scheduling results. Considering the dynamicity of the various emergencies in the discrete job-shop, a multi-level dynamic scheduling model was proposed based on rolling window. The model integrates the merits of periodic rescheduling and event-driven rescheduling to reduce the scheduling cost and mitigate the impact of disturbances, without sacrificing the stability and efficiency of production. Our method was verified through discrete event simulation. 31 refs.
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Key Words: *Discrete Job-Shop Scheduling Problem (DJSP), Bi-Directional Scheduling, Genetic Algorithm (GA), Rolling Window, Discrete Event Simulation*

Pages 529-539

DYNAMIC SCHEDULING OF BLOCKING FLOW-SHOP BASED ON MULTI-POPULATION ACO ALGORITHM

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Abstract
Drawing on the coevolution between populations, this paper proposes a dynamic multi-population ant colony optimization (ACO) algorithm to solve the blocking flow-shop scheduling problem (FSP). In our algorithm, the ant colony is divided into an elite population, multiple search populations, and a mutation population. In the initial stage, only the elite population and the search populations participate in optimization. After a certain number of iterations, a mutation population is dynamically generated from the worst solution in each search population and that in the elite population. The mutation population is reinitialized before entering the optimization process. The mutated population can jump out of the original search space for another search. Finally, the superiority of our algorithm in solving blocking FSP was proved through comparative simulations. 35 refs.
(Received in June 2020, accepted in August 2020. This paper was with the authors 5 weeks for 1 revision.)

Key Words: *Flow-Shop Scheduling Problem (FSP), Dynamic Job-Shop Scheduling, Multi-Population Ant Colony Optimization (ACO) Algorithm, Discrete Event Simulation*