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Intelligent manufacturing: New advances and challenges

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Since its humble infancy to turn a natural resource into a valuable product in the most economic, efficient, and effective way, manufacturing has been extensively practiced so as to optimize the interplay among people, machines, and materials. In the past decades, remarkable achievements have been witnessed in computation and communication technologies, facilitating the applicability of more sophisticated system configurations and requirements. At the same time, the maturity of manufacturing technologies has in turn spawned the continuing conception, development, and deployment of new relevant applications such as warehouse, logistics, and energy. All these stimulate researchers to keep working for decades to integrate recent achievements into production processes, envisaging more advancements and developments of intelligent manufacturing.

Despite many accomplishments in the area, fundamental challenges remain to be addressed. Numerous approaches are still in their transition from laboratory environments into real-world applications. To further advance the field, tangible and measurable progresses are needed not only in the theoretical foundations but also in technical innovations. On one side, sustainable and reproducible performances necessitate new theories on systems' modelling, analysis, and control. On another side, promising techniques mandate new requirements on metrics like robustness, optimality, and sensitivity.

As a response to the aforementioned achievements and challenges, this special issue is committed to capturing the current application and technology trends in intelligent manufacturing. To be practical, techniques are emphasized more than theoretical contributions. With topics spanning the area from multi-objective optimization, job-shop cell scheduling, to risk management planning and others, these nine carefully-selected papers are connected by a common theme: the application of recent intelligence technologies. Each of the contributions also finds a unique niche in the spectrum of current approaches, highlights challenging issues, presents new compelling solutions, and hopefully will inspire more research interest.

Zeng et al. describe the problem of parts scheduling in multijob shop cells by considering exceptional parts that need to visit machines in different cells and be transferred by robot with the objective of minimizing the make-span. The authors are trying to develop an NLP mathematical model based on objective function and assumptions. In order to mitigate the relatively large problem complexity, They further propose a two-stage algorithm, which involves both Intra-cell scheduling and Inter-cell scheduling. These two stages determine the sequence of operations on the same machine, operation transfers by robots, and the sequence of parts from different cells that need to be processed on the same machine, respectively. A neighborhood based on the disjunctive graph model is applied to guarantee the efficiency of the proposed algorithm. To check the efficiency of the two-stage algorithm, a series of test problem are generated. The solution obtained by the proposed two-stage algorithm is compared to the optimal

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values obtained by CPLEX 12.1 based on the NLP mathematical model on test problems. These tests demonstrated that the proposed two-stage algorithm is a good method for solving this type of scheduling problem.

Wang et al. describe a hybrid estimation of distribution (HEDA) algorithm in order to solve the semiconductor final testing scheduling problem. The probability model-based estimation of distribution (EDA) sampling and the local search procedure are combined to stress global exploration and local intensification together. Innovative and effective encoding and decoding methods are proposed to map from the solution space to the schedule space. The authors design a probability model to describe the distribution of the solution space and generate the new individuals of the population. As well, a new mechanism is developed to update the parameters of the probability model with the superior solutions. To enhance the exploitation ability of the algorithm, the authors hybridize the algorithm by a local search procedure. Moreover, the influence of parameter setting is investigated by using design-of-experiment based testing. Simulation tests and comparisons to several existing algorithms demonstrate the effectiveness and efficiency of the proposed HEDA in solving the concerned problem.

Li et al. describe a heuristic-search genetic algorithm (HSGA) to schedule a multi-stage hybrid flow shop (HFS) with single processing machines and batch processing machines. In their algorithm, genetic algorithm (GA) is adopted to search appropriate heuristic rules for machines and parts simultaneously, and then parts and machines are scheduled using the obtained heuristics of the combinatorial rules. According to the comparison experiments, the HSGA outperforms the combinatorial heuristic rules and other heuristic-search approaches using different encoding schemes. Moreover, as compared with the CPLEX, for the test problems with multiple batch processing machines, the HSGA provides significantly better solutions, and for those test problems with only one batch processing machine, the average gaps between the HSGA and the CPLEX are only 0.84 and 9.32 %, with respect to minimizing the maximum completion time and minimizing the total weighted tardiness, respectively. According to the sensitivity analysis, the HSGA is robust to the changing release time patterns and due date settings. In addition, the experiments on computational efficiency indicate the HSGA has a significant advantage as compared with the meta-heuristic operating directly on the search space of scheduling solutions, and therefore it is suitable to solve large dimension scheduling problems.

Li et al. describe a multi-objective optimization approach, based on neural network, to optimize the cutting parameters in sculptured parts machining, which are is quite essential in process planning of sculptured parts to reduce machining cost and increase surface quality. An optimization mathematical model is first presented with spindle speed, feed rate, depth of cut and path spacing as the process parameters and machining time, energy consumption and surface roughness as objectives. Then a Back propagation neural network (BPNN) model is developed to predict cutting parameter, and experiments are designed to train and test the validation of developed BPNN model. Through large numbers of training and testing, the developed BPNN model can help decision-makers to accurately predict the optimal cutting parameters through comparison with the traditional method in terms of machining time, energy consumption and surface roughness.

Jiang et al. describe a method to minimize risk in the operation of a project so as to ensure its success. This is a major concern in virtual enterprises (VEs). In practice, a VE is always in an environment with unpredictable change and dynamic markets, being susceptible to risks. The authors are trying to develop a novel three-level dynamic risk-management planning model for VEs focusing on project organization mode and risk dynamic features with the objective to maximize the completion probability under the constraints of cost, due date, and quality. The first level adopts non-linear integer programming techniques, the second level evaluates the risk for the whole project based on network analysis, and the third level assesses the risk for a single process with the aid of a Markov process. As a consequence, an algorithm integrating with genetic algorithm plus simulated annealing/critical path method/Markov (GACSA/CPM/Markov) is designed to solve the problem and compared with GA and SA-based methods, respectively. Experimental results show that the proposed algorithm is effective and the three level model can deal with dynamic risks for VEs.

Li et al. describe a framework to analyze the overall carbon emissions of a computer numerical control (CNC)-based machining system. A wide range of operational activities that directly or indirectly contribute to the total carbon emissions of the system are considered, which include the production of energy and material necessary for and the disposal of chips resulted from machining operations. The application of the proposed model is then demonstrated through examples of machining a turning workpiece and a gear, respectively. The importance of the model is evident that it provides a quantitative method to understand and evaluate carbon emissions of a CNC-based system with respect to different machining parameters. The use of their developed model to more industrial cases of different cutting tools, cutting processes, size and shape of workpieces can further practitioners' understanding on the interplay of those variables on the overall carbon emissions of a CNC-based system. As suggested by the experimental example, there exists an optimum scheme where cutting parameters are optimized to achieve a balance of process efficiency and carbon emissions.

Li et al. describe a method to evaluate the status and reliability of cutting tools with the aid of logistic regression

models and acoustic emission signals. The authors' experimental data show that acoustic emission and cutting force signals have a better linear relationship with the wearing process of a cutting tool. Therefore, they can be employed to assess the degradation process of a cutting tool. On the basis of the cutting force and acoustic emission signals, the authors develop two reliable estimation models. One considers both parameters whereas another considers only the latter. Both models can successfully and independently estimate the reliability. In practice, it is cumbersome to measurer the cutting force. Thus, a more practical method to assess cutting tool status relies on the combination of logistic regression models and acoustic emission signals. Experimental results verify the effectiveness of this method.

Li et al. describe a Petri net oriented scheduling solutions to a flexible manufacturing system (FMS), where the production process and constraints can be modeled by Petri nets concisely. The authors's effort is to mitigate the search space for an optimal or suboptimal schedule, which always grow exponentially with the increase of problem size. By considering the scheduling problems of FMS in the framework of timed-transition Petri nets, each token owns a individual timestamp which facilitates the analysis of the concurrency characteristic of modeled system. To save search effort, an admissible heuristic function is proposed. This also considers the available time of shared machine resources and subparts during calculating the lower bound of the remaining time for unprocessed operations. Their work proves that the heuristic function is more effective than prior ones. Thus, an optimal scheduling strategy can be obtained at much less effort. Several numerical experiments are provided to demonstrate the effect of the improved heuristic function.

Chandrasekaran et al. describe a software tool in order to implement varisous liveness enforcing supervisory policies (LESPs) for a class of Petri net structures that model automated manufacturing systems that are prone to livelocks. This class is identified by the property that the existence of an LESP for an instance initialized with a marking implies the existence of an LESP when the same instance is initialized with a larger marking. If a minimally restrictive LESP prevents the occurrence of a transition at some marking for an instance, then every LESP for the instance should prevent the occurrence of the transition for the same marking. There is a unique minimally restrictive LESP for a Petri net that has an LESP. After reviewing the relevant theory, the authors develop the implementation details of a procedure for the automatic synthesis of the minimally restrictive LESP for any instance from the aforementioned class.

Despite our effort to include most recently-emerging applications and perspectives of intelligent manufacturing, our coverage is necessarily incomplete. What we have captured in this special issue can only represent a snapshot of the whole story. There must be many fascinating areas that are not appropriately covered. Nevertheless, we hope that this collection of articles can present the current advancements and future challenges, and motivate more interest and further discussion on these topics and beyond.

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