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Technical paper

The simulation design and analysis of a Flexible Manufacturing System with Automated Guided Vehicle System

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ABSTRACT

This paper presents the simulation design and analysis of a Flexible Manufacturing System (FMS) with an Automated Guided Vehicle system (AGVs). To maximize the operating performance of FMS with AGVs, many parameters must be considered, including the number, velocity, and dispatching rule of AGV, part-types, scheduling, and buffer sizes. Of the various critical factors, we consider the following three: (1) minimizing the congestion; (2) minimizing the vehicle utilization; and (3) maximizing the throughput. In this paper, we consider the systematic analysis methods that combine a simulation-based analytic and optimization technique that is Multi-Objective Non-Linear Programming (MONLP) and Evolution Strategy (ES). MONLP determines the design parameters of the system through multi-factorial and regression analyses. ES is used to verify each parameter for simulation-based optimization. A validation test for the two methods is conducted. This method-based approach towards design yields the correct experimental results, ensures confidence in the specification of design parameters and supports a robust framework for analysis.

1. Introduction

A Flexible Manufacturing System (FMS) consists of a Numerically Controlled (NC) machine, a Material Handling System (MHS), and a computer control system for integrating the NC machine and the MHS [1]. The Integration of these machines and facilities generally involves the use of a controller, complex software and an overall computer control network that coordinates the machine tools, the material handling, and the parts [2,3]. Material handling in FMS is becoming easier with advances in automated-machine technology. The rapid development in technology presents manufacturing firms with a variety of alternatives for in-plant transportation [4].

In FMS, the Automated Guided Vehicle system (AGVs) is an excellent choice for MHS because of its automation of loading and unloading, flexibility in path movement, ease of modification of the guide-path network and computer control. AGVs can be used in two different ways. The first approach is to attach a part to the AGV that helps to execute all manufacturing processes by carrying the part from station to station. In this approach, the AGV is freed only after all the processes are completed for the part. The second approach is to use the vehicle only for moving the part from one station to another. The vehicle is assigned to the part only for a single trip [4]. In this paper, we analyze the latter case for the FMS with AGVs, because the required number of vehicles is significantly less than in the former case.

FMS are complex and expensive systems that require an accurate designing phase. In particular, it is important to closely examine the dynamic behavior of the different FMS components to predict the performance of the production system [5]. Simulation analysis is perhaps the best technique to use for an intricate system that cannot be easily described by analytical or mathematical models [6,7].

There are a number of commercially available software tools or simulators for assisting in the design and analysis of FMS [8]. There are two broad approaches in such software. One is the use of a general simulation language, such as GPSS/H, SLAM II, SIMAN IV, SIMULA, etc., to build specific FMS simulation software or simulators. The other is the direct use of an FMS simulator that has been developed using some general computer languages such as FORTRAN, Pascal, or C or even some general simulation language that is combined with C, LISP, or PROLOG, to yield applications such as AutoMod II, Simfactory II.5, FACTOR, FMS++, and MAST, for simulating manufacturing systems or FMS [9].

Many researchers have suggested various approaches for FMS design and analysis [10,11]. The execution of simulation models reveals the basic operations of the proposed models. Then, the designer analyzes the output to determine whether the expected design objectives can be achieved [12]. In the manufacturing field, the simulation can be used to configure the production system,

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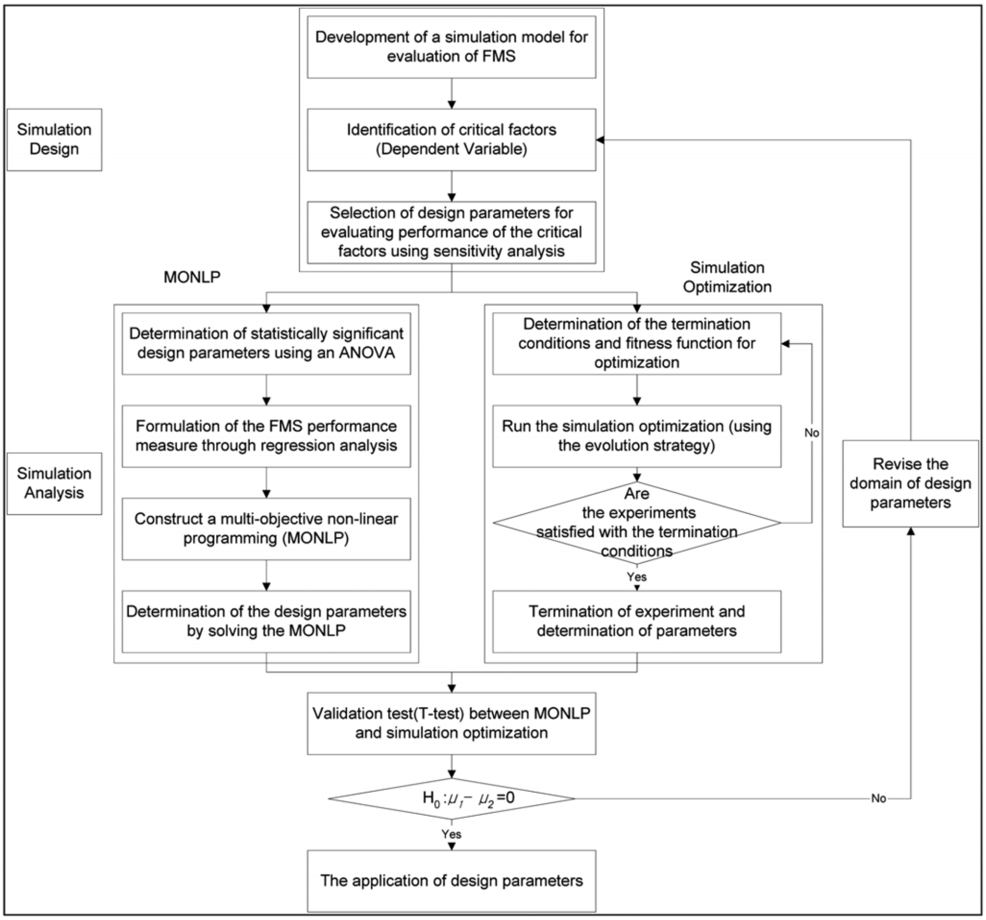

Fig. 1. Simulation design and analysis of FMS with AGVs.

or to select more appropriate management rules [13]. Engineering economics and operational research and management science methodologies and techniques have been applied to obtain performance data (e.g., lead-time, productivity, cost, flexibility, and product quality) for different configurations [14,15]. Hlupic and Paul present the use of activity cycle diagram as a graphical method for developing simulation models for the conceptual FMS [16]. Borenstein describes an intelligent decision support system for the analysis and evaluation of FMS [17]. Chan et al. present the integrated approach for the design of FMS, which uses simulation and multi-criteria decision making techniques. Intelligent tools (such as expert systems, fuzzy systems and neural networks), have been developed for supporting the FMS design process [18]. Anglani et al. present a method to develop FMS simulation models, based on the unified modeling language (UML) analysis/design tools and simulation software. This method improves the software development efficiency through a rule-based approach and adds fundamental object-oriented features to the specific software environment [5].

Each approach provides some insight into the underlying functioning of FMS. To a large degree, our understanding of FMS is fragmented as there are significant differences in assumptions, constraints, modeling techniques, solution strategies, criteria, objectives, and decision processes. The results that are obtained for one decision situation may not apply in others [19]. Thus, a general and effective method is needed for the analysis of FMS. Therefore we propose to use a simulation-based analytic and optimization technique, namely, Multi-Objective Non-Linear Programming (MONLP) and Evolution Strategy (ES), to analyze the influence of design parameters on various critical factors. The objectives of the simulation analysis are as follows:

- To quantify the effects of design parameters on the performance vis-à-vis critical factors.
- To highlight the significant design parameters.
- To determine the interaction between design parameters.
- To verify the validation between MONLP and ES.

This paper is organized as follows. Section 2 describes a systematic method of designing and analyzing FMS. A hypothetical simulation model for the FMS is proposed in Section 3. The selection of the critical factors and design parameters is presented in Section 4. In Section 4, we present our experiment and procedure for the MONLP, simulation-based optimization, and validation test. Finally, Section 5 presents the study conclusions.

2. A method for the design and analysis of FMS

In most research on the design and analysis of FMS or manufacturing, the simulation modeling and analysis are separated. The output (i.e., throughput, machine utilization, congestion, work-in-process, etc.) that is produced by the execution of simulation models is input to the simulation analysis. The design and operational parameters and critical factors realized by the simulation analysis are then shown to the operators. Then, the parameters of the simulation models are manually modified. This iterative process continues until the design is accepted [18].

In this paper, we present a systematic approach for the design and analysis of FMS with AGVs by (1) determining the critical factors, (2) considering both the design and operational parameters that have an effect on the critical factors, (3) conducting a systematic method of analysis that combines MONLP and ES, and (4) executing the validation test between MONLP and ES. The simulation