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Optimization of an Automated Storage and Retrieval Systems by Swarm Intelligence

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Abstract

Automated storage and retrieval systems (AS/RS) need to execute complex combinatorial and sorting tasks. In this study we have shown how to plan AS/RS using multiple objective ant colony optimisation (ACO). The distribution of products in the AS/RS is based on the factor of inquiry (FOI), product height (PH), storage space usage (SSU) and path to dispatch (PD). The factor of inquiry for any product can be adjusted during the storage process in regard to actual market requirements. In order to reduce space consumption and minimise investment costs we chose an AS/RS with no corridors and one single elevator for multiple products. Results show that the expected distribution of products was reached and that ACO can be successfully used for planning automated storage systems.

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Keywords: automated storage and retrival system; automatisation; multi-objective optimisation; swarm intelligence

1. Introduction

Today, more than ever, the evolution of automatic storage and retrieval systems (AS/RS) is accelerating. Due to steadily growing economic and logistic needs and the fact that more goods need to be stored, AS/RS constantly call for further optimisations. Advanced storage systems allow automatic storage and retrieval of goods with

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management and control of all automated processes from one place. The two more used approaches for AS/RS design and study in present days are analytical optimisations and simulations. Optimisation of the AS/RS operation using modern algorithms was studied by authors such as Lerher, Šraml, Borovišek, Potrč [1] and Yang, Miao, Xue and Qin [2]. Studies which present general overviews of warehouse design and control were presented by de Koster, Le-Duc and Roodbergen [3], Gu, Goetschalckx and McGinnis [4] and Baker and Canessa (2009) [5]. Design of a compact 3D AS/RS was proposed by de Koster, Le-Duc and Yugang [6], Kuo, Krishnamurthy and Malmborg, proposed computationally efficient design conceptualization models for unit-load AS/RSs based on autonomous vehicle technology (AVS/RS) [7] and Manzini, Gamberi and Regattieri presented a multi-parametric dynamic model of a product-to-picker storage system with class-based storage allocation of products [8]. More specific research was presented by Fukunari, Malmborg, Hur, Nam, Yin, Rau, Dooly, Lee and others. Fukunari and Malmborg invented the term ‘‘interleaving’’, which refers to the pairing of storage and retrieval transactions on the same cycle to generate DC cycle cycles [9]. Hur and Nam presented stochastic approaches for the performance estimation of a unit-load AS/RS [10], Yin and Rau studied the dynamic selection of sequencing rules for class-based unit-load AS/RS [11]. Dooly and Lee presented a shift-based sequencing problem for twin shuttle AS/RS [12]. In an overall state-of-the-art review authors Roodbergen and Vis [13] found that the strength of simulation could be better exploited in AS/RS researches by comparing numerous designs, whilst taking into account more design aspects, especially in combination with different control policies. They proposed that sensitivity analyses on input factors should also be performed such that a design can be obtained which can perform well within all applicable scenarios.

For our research we chose a non-traditional, unit-load, deep-lane type AS/RS. The unit-load AS/RS is typically a large automated system designed to handle unit-loads stored on pallets or within other standard containers. The system is computer controlled and the stacker cranes are automated and designed to handle unit-load containers. The deep-lane AS/RS is a high density unit-load system that is appropriate when large quantities of stock are stored but the number of separate stock types is relatively small. The loads can be stored to greater depths. Load identification is the primary role for automatically identifying AS/RSs. The scanners are located at the inlet location, to scan a product’s identification code. The data is sent to the AS/RS computer which, upon receipt of load identifications, assigns and directs the load to the storage location [14]. Based on the fact that corridors (aisles) use a lot of the available storage space and stacker cranes costs can reach up to 40% of the complete AS/RS investment, we decided to plan an AS/RS completely without corridors and with one major stacker crane with multiple loading sites, able to supply the complete AS/RS. Planning the layout of our AS/RS was based on a table of inquiry and the frequencies when manufacturing individual products. Distribution of products during an AS/RS operation is dependent on factor of inquiry (FOI), product height (PH), storage space usage (SSU) and path to dispatch (PD). Another boundary condition included within our optimisation algorithm is that the factor of inquiry may change dynamically during AS/RS operation regarding actual market requirements. Considering all the parameters resulted in a multi-objective optimisation problem. We chose the particle swarm intelligence (PSO) algorithm for the optimisation as it promises good results for complex combinatorial tasks similar to ours [15, 16, 17].

2. Used methods

Swarm intelligence (SI) is the collective behaviour of decentralised, self-organised systems, natural or artificial. The expression was introduced by Gerardo Beni and Jing Wang in 1989 within the context of cellular robotic systems. SI systems typically consist of a population of simple agents or bodies interacting locally with one another and with their environments. The inspiration often comes from nature, especially biological systems. The agents follow very simple rules and although there is no centralised control structure dictating how individual agents should behave local, and to a certain degree, random interactions between such agents lead to the emergence of intelligent global behaviour, unknown to the individual agents. Examples in natural systems of SI include ant colonies, bird flocking, animal herding, bacterial growth, and fish schooling. The definition of swarm intelligence is still rather unclear. In principle, it should be a multi-agent system that has self-organised behaviour that shows some intelligent behaviour [18].

Particle swarm optimisation (PSO) is a global optimisation algorithm for dealing with problems in which a better solution can be represented as a point or surface within an n-dimensional space. Hypotheses are plotted within this space and seeded with an initial velocity, as well as a communication channel between the particles. The particles